RESEARCH MEMORANDUM

ALTITUDE PERFORMANCE AND OPERATIONAL CHARACTERISTICS

OF AN XT38-A-2 TURBOPROP ENGINE

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

The over-all engine performance and the starting and windmilling characteristics of an XT38-A-2 turboprop engine have been investigated in the NACA Lewis altitude wind tunnel. The simulated flight conditions ranged from altitudes of 5000 to 45,000 feet at a flight Mach number of 0.30 and from Mach numbers of 0.301 to 0.557 at an altitude of 35,000 feet. The engine, equipped with a standard-area exhaust nozzle, was operated with independent control of fuel flow and propeller pitch; operation was thereby allowed over a wide range of engine conditions. Windmilling characteristics were obtained at altitudes of 15,000 and 35,000 feet.

Analysis of the performance maps obtained at each flight condition revealed that both altitude and flight Mach number had a major effect on corrected engine variables. The large reductions in corrected shaft horsepower occurring when the altitude was increased were the result of decreases in compressor and turbine efficiencies. Windmilling engine starts were made at altitudes as high as 35,000 feet at an engine speed of 2000 rpm.

INTRODUCTION

An investigation of the performance of an XT38-A-2 turboprop engine over a range of simulated altitude conditions has been conducted in the NACA Lewis altitude wind tunnel. Steady-state engine performance, component performance, and starting and windmilling characteristics, as well as the dynamics of the engine, were studied. Reported herein are the over-all engine performance and the starting and windmilling characteristics.

The simulated flight conditions ranged from altitudes of 5000 to 45,000 feet at an average flight Mach number of 0.30 and from Mach numbers of 0.301 to 0.557 at an altitude of 35,000 feet. A standard exhaust nozzle having an area of 244 square inches was used. Independent control of propeller and fuel flow permitted operation at various engine speeds over a wide range of turbine-inlet temperature. Engine windmilling characteristics at various airspeeds and blade angles were obtained at altitudes of 15,000 and 35,000 feet.

Data are presented in the form of performance maps at each flight condition to show the effects of altitude and flight Mach number on various engine-performance variables. The effect of engine deterioration with operating time on performance is also discussed.

All symbols used in this report are defined in appendix A.

APPARATUS

Description of Engine

The main components of the engine include a 19-stage axial-flow compressor, eight cylindrical combustion chambers, a four-stage turbine, an exhaust cone, and a planetary reduction-gear assembly with a 12.5:1 gear ratio. The engine was fitted for this investigation with a three-blade propeller, 13 feet in diameter. The maximum diameter of the flight engine mount is $37\frac{1}{2}$ inches; the length from the foremost end of the propeller shaft to the exhaust-nozzle outlet is 157 inches. The net dry weight of the engine including power section, gearbox, control, torquemeter, and flight frame, but without propeller, is approximately 1660 pounds. The exhaust-nozzle-outlet area is 244 square inches.

The operating limits of the engine as established by the manufacturer are:

Operating condition	Engine speed, rpm	Turbine-inlet temperature, $^{\circ}R$	Time limit, min
Military	14,300	2060	30
100 percent normal power	14,300	1960	None
80 percent normal power	14,300	1840	None
60 percent normal power	14,300	1720	None

At military operating conditions, the nominal static sea-level rating is 2520 shaft horsepower and a jet thrust of 603 pounds. The engine air flow is approximately 30 pounds per second. The aerodynamic design point of the engine is at an altitude of 15,000 feet and a flight Mach number of 0.347.

Installation and Instrumentation

The altitude wind tunnel is a closed-circuit, return-type tunnel circular in cross section with a test section 20 feet in diameter and 40 feet long. As shown in figure 1, the engine was mounted on a thin wing section spanning the test section. Desired air velocities through the tunnel test section are provided by a variable-pitch 18-blade fan driven by an 18,000-horsepower electric motor. The installation was streamlined by providing a cowling about the entire engine, a wooden lip at the inlet-air duct, and a conical fairing for the propeller hub region.

A view of the engine showing the location of the components and the measuring stations is shown in figure 2. Schematic diagrams of the instrumentation at six of the stations are given in figure 3. The six parallel control thermocouples at the turbine-inlet area were installed to produce a single indication of turbine-inlet temperature. The air flow was determined from measurements at station 1 and was checked at stations 1 and 2. Air leakages occurring in various sections of the engine were measured when possible or were assumed to be a percentage of the inlet-air flow. These leakages are described in appendix B. Water-filled manometers were used to measure pressures at every station except the compressor outlet and turbine inlet, where mercury-filled manometers were used. Iron-constantan thermocouples were used in the measurement of engine-inlet and compressor-outlet air temperatures; chromel-alumel thermocouples were used in the measurement of turbine-inlet and exhaust-nozzle gas temperatures. All temperatures were automatically recorded with self-balancing potentiometers.

A stroboscopic tachometer, in conjunction with a continuously indicating tachometer, measured engine speed. Torque was measured by a magnetic pickup-type torquemeter, which sensed the torsional deflection of the shaft between the power section and the reduction gearbox. This torsional deflection was measured electronically and indicated on a milliammeter. To determine contamination of tunnel air induced by the engine exhaust, an oxygen analyzer, employing the standard thermal-conductivity method to determine the oxygen content of gas, was used to sample the air at the entrance of the inlet duct. A slip ring on the propeller shaft and a slide-wire arrangement on one of the three blades indicated propeller-blade angle on a milliammeter.

PROCEDURE

Independent control of propeller pitch and fuel flow was used to obtain data over a range of power (turbine-inlet temperature) at each of several engine speeds ranging from about 92 to 104 percent of rated speed. To eliminate inlet-duct losses from the engine performance, the tunnel test-section velocity was set to give the desired ram-pressure ratio based on compressor-inlet total pressure and free-stream static pressure. The methods used to compute the engine-performance variables are included in appendix B.

The initial 20 hours of engine operation at altitude were used to determine the vibration characteristics of the propeller. Data from this period of the investigation will not be presented. Regular engine-performance data were obtained during the next 85 hours of engine time. To aid in explaining any inconsistencies in data due to deterioration, which has been found to be an important factor in some turboprop engines (ref. 1), and data irregularities due to changes in components during the program, the order of performance tests is given in the following table:

Engine time, hr	Data obtained at:	
	Altitude, ft	Flight Mach number
20-25	25,000	0.291
33-40	35,000	.301
40-47	35,000	.438
47-59	35,000	.557
60-82	5,000	.300
83	Turbine-assembly change	
91-96	45,000	0.294
96-105	15,000	.303

The turbine labyrinth seal was found damaged at about 83 hours engine time; performance obtained after that time was with a new turbine section. At an altitude of 25,000 feet and a flight Mach number of 0.30, a given engine condition was run approximately every 10 hours to check engine and component deterioration.

Engine windmilling characteristics were obtained for a range of propeller-blade angle at the following altitudes and airspeeds:

Altitude, ft	True airspeed, knots
15,000	66, 110, 155
35,000	115, 165, 215

During the investigation, engine-inlet temperatures were maintained as near to NACA standard altitude conditions as facility limits allowed. In general, engine-inlet temperature ranged from 80° to -30° F for steady-state running. By precooling the tunnel, engine starting characteristics were obtained at temperatures as low as -50° F.

Fuel used during the investigation was clear gasoline having a lower heating value of 18,925 Btu per pound and a hydrogen-carbon ratio of 0.182. Several types of lubricating oil were used during the investigation to lubricate both the gearbox and power section. The types used are designated PRL 3313, PRL 3161, and EEL 3A, all of which were approved by the engine manufacturer.

RESULTS AND DISCUSSION

Performance Characteristics

Inlet-air flow. - At the start of the investigation, a study was made of the flow conditions of the air entering the compressor inlet. The pressures indicated by the four rakes at station 2 showed the flow through the duct and around the shaft to be fairly uniform radially and circumferentially. Total pressures at the bottom rake were about 1 percent lower than the average inlet pressure. Data indicated by the oxygen analyzer showed that the oxygen content of the engine-inlet air never reached a value below 19.5 percent as compared with standard conditions of 20.9 percent.

Generalized performance. - All the engine-performance data in both corrected and uncorrected form are presented in table I. Data typical of those obtained at all the various flight conditions are presented in figures 4 and 5 for an altitude of 15,000 feet and a flight Mach number of 0.303. Variation of corrected turbine-inlet temperature, corrected jet thrust, and specific fuel consumption with corrected shaft horsepower at seven engine speeds is shown in figure 4.

In varying engine speed at a constant corrected turbine-inlet temperature (fig. 4), a maximum shaft horsepower is reached. At the military-rated corrected turbine-inlet temperature of 2060° R, an increase in corrected engine speed from 13,690 to 15,270 rpm varied the corrected shaft horsepower from 2460 horsepower at 13,690 rpm to a maximum of 2570 horsepower at 14,600 rpm. For the same conditions, corrected jet thrust increased from 555 to 660 pounds and specific fuel consumption increased from 0.65 to 0.68 pound of fuel per shaft horsepower per hour. The effect of corrected engine speed on corrected air flow is shown in figure 5. There did not appear to be any effect of turbine-inlet temperature level on corrected air flow. The air flow at the rated corrected engine speed of 14,300 rpm was 29.35 pounds per second.

Cross plotting of the engine-performance parameters of figure 4 for each flight condition provided the engine-performance maps presented in figure 6 for the seven flight conditions investigated. In these maps, corrected shaft horsepower is plotted against corrected engine speed for constant values of corrected turbine-inlet temperature, corrected jet thrust, and specific fuel consumption. From these maps the performance at any engine operating condition can be determined for each flight condition investigated.

In general, the maximum corrected horsepower at a fixed corrected turbine-inlet temperature occurred at corrected engine speeds between 13,200 and 14,800 rpm, depending on flight condition and level of turbine-inlet temperature. As corrected engine speed increased, there was, however, a continuous increase in both corrected jet thrust and specific fuel consumption for any given corrected turbine-inlet temperature.

As can be seen from these maps, at a flight Mach number of 0.30, performance at an altitude of 15,000 feet is generally better than at 5,000 feet and performance at 45,000 feet is better than at 35,000 feet altitude. These comparisons are inconsistent with the performance trends for the other flight conditions, which show the conventional performance deterioration as altitude was increased. The apparent discrepancy can be explained by the manner in which the engine performance was affected by the aforementioned turbine change which immediately preceded the runs at altitudes of 15,000 and 45,000 feet. Performance obtained prior to and following the turbine change is shown in figures 7 and 8. Engine-performance data, obtained at a given operating condition at an altitude of 25,000 feet and a flight Mach number near 0.30 in order to check engine deterioration, are presented in figure 7 in terms of standard engine-performance parameters. The performance decreased slightly during the first 20 hours of operation and then remained essentially constant until the turbine section was replaced. After the replacement, engine performance improved at this particular flight condition. To further illustrate this difference, data from a brief investigation of engine performance at an altitude of 15,000 feet before the turbine change are compared in figure 8(a) with values from a complete performance map taken after the change. In figure 8(b), values from a map taken before the change are compared with some limited data after the change for an altitude of 25,000 feet. Performance at a given turbine temperature level at both altitudes was better after the change by approximately 200 to 300 corrected horsepower. With this marked change considered, the subsequent results and discussion will involve only the performance data obtained between 20 and 82 hours engine time. The data presented herein consequently indicate only the approximate level of performance of this engine model, but the trends are considered typical.

Effect of altitude. - Specific effects of altitude on engine performance at a flight Mach number of 0.30 are presented in figure 9. Performance in terms of corrected shaft horsepower, corrected jet thrust, and specific fuel consumption is shown at three temperature levels and several engine speeds. Altitude had a major effect on shaft horsepower and specific fuel consumption, but a minor effect on jet thrust. At a corrected turbine-inlet temperature of 2200° R and an engine speed of 15,500 rpm, corrected shaft horsepower decreased from 2840 horsepower at an altitude of 5000 feet to 2020 horsepower at an altitude of 35,000 feet; corrected jet thrust increased from 660 to 700 pounds, and specific fuel consumption increased from 0.655 to 0.935 pound of fuel per shaft horsepower per hour for the same altitude variation. This change in shaft horsepower, which amounts to 28.8 percent, is primarily a result of the reductions in compressor and turbine efficiencies with altitude (shown in fig. 10). Performance of the compressor and turbine are presented for corrected engine speeds between 14,500 and 16,000 rpm at a corrected turbine-inlet temperature of 2200° R. At a corrected engine speed of 15,500 rpm, an increase in altitude from 5,000 to 35,000 feet resulted in a decrease in compressor efficiency from 74.6 to 71.5 percent and a decrease in turbine efficiency from 81.7 to 77.0 percent. Because at this operating condition the work split between the compressor and the propeller shaft is such that about 2/3 of turbine work is absorbed by the compressor, a small drop in compressor efficiency can impose a large loss in shaft output. If, in addition, the turbine exhibits a drop in efficiency, the loss in shaft power is further increased. The individual contribution of each component to the performance loss with altitude is shown in figure 11. Although the actual gearbox loss varies from approximately 20 to 40 horsepower in this range of altitude, it can be seen that at high altitudes it represents a greater part of the shaft horsepower than at sea level. If the previously quoted reductions in compressor and turbine efficiencies had not occurred as the altitude was increased, the corrected horsepower would be as shown in figure 11(a), while specific fuel consumption would be as shown in figure 11(b). All the variation of performance with altitude has thus been accounted for by the compressor, turbine, and gearbox losses. These effects appear to be typical for turboprop engines and stress the fact that reducing or eliminating altitude effects on engine components is much more important for turboprop engines than for turbojet engines.

Effect of flight Mach number. - Some specific effects of flight Mach number on performance at an altitude of 35,000 feet are presented in figures 12 and 13. Brief investigations at flight Mach numbers of 0.349 and 0.513 at this altitude augmented the full performance maps presented in figure 6(d) to (f). The performance at a corrected engine speed of 15,500 rpm over a range of corrected turbine-inlet temperature is shown in figure 12; the variation of performance with several corrected engine speeds at a corrected turbine-inlet temperature of 2300° R is shown in figure 13. As the flight Mach number was increased at either constant corrected engine speed or turbine-inlet temperature, corrected shaft horsepower and jet thrust increased while specific fuel consumption decreased. Specifically, as the flight Mach number was increased from 0.30 to 0.56 at a corrected engine speed of 15,500 rpm and a corrected turbine-inlet temperature of 2400° R, the corrected shaft horsepower increased from 2740 to 3130 horsepower, the corrected jet thrust increased from 810 to 965 pounds, and the specific fuel consumption decreased from 0.810 to 0.695 pound of fuel per shaft horsepower per hour.

Operational Characteristics

Windmilling. - The variation of engine windmilling speed with propeller-blade angle is shown in figure 14(a) for an altitude of 15,000 feet and true airspeeds of 66, 110, and 155 knots and in figure 14(b) for an altitude of 35,000 feet and true airspeeds of 115, 165, and 215 knots. Maximum windmilling speed was obtained with a blade angle of approximately 24°, and there appeared to be little effect of altitude on the maximum windmilling speed for any given true airspeed. At that blade angle, an engine windmilling speed in excess of rated speed could be encountered at airspeeds above about 218 knots at any altitude. The variation of corrected air flow with corrected engine speed for the engine in windmilling condition is shown in figure 15. At the rated corrected engine speed of 14,300 rpm, the corrected air flow was 28.9 pounds per second; while at half that corrected speed, the air flow was only 8 pounds per second.

Starting. - Examination of the starting characteristics of the engine reveals two distinct regions of operation depending on the fuel system employed, as shown in figure 16. At engine windmilling speeds between 2600 and 3600 rpm, starts with the standard fuel control were made up to an altitude of 21,000 feet, but no starts were obtainable at higher altitudes (fig. 16(a)). The engine fuel was at room temperature, while the engine-inlet temperature was as low as -20° F for these starts. Another fuel control, which allowed much lower starting fuel flows than the standard control, was installed for the dynamics investigation; use of this fuel control resulted in engine starts at an altitude as high as 35,000 feet and with windmilling speeds as low as 2000 rpm. The engine-inlet temperature was -50° F.

Oil foaming. - Engine operation at altitudes above 30,000 feet with PRL 3313 and PRL 3161 oils in the gearbox and power section resulted in foaming and subsequent loss of oil by vent spewing due to reduced scavenge-pump capacity. In one instance the gearbox became loaded with oil and overheated beyond specification limits necessitating replacement of the gearbox. The problem of foaming was alleviated by use of EEL 3A lubricating oil along with pressurization of the gear case above an altitude of 30,000 feet at a gage pressure of about 5 pounds per square inch.

CONCLUSIONS

The performance of an XT38-A-2 turboprop engine was investigated at simulated flight conditions ranging from altitudes of 5,000 to 45,000 feet at a flight Mach number of 0.30 and from Mach numbers of 0.301 to 0.557 at an altitude of 35,000 feet.

The investigation indicated that the large reductions in corrected shaft horsepower, which occurred when altitude was increased, are due principally to decreases in compressor and turbine efficiencies. An increase in altitude from 5,000 to 35,000 feet at constant corrected turbine-inlet temperature and engine speed resulted in reductions of approximately 3 and 5 percent in compressor and turbine efficiencies, respectively, and a net loss of 28.8 percent in corrected shaft horsepower. At a given flight condition and a fixed corrected turbine-inlet temperature, operating the engine at a corrected engine speed between 13,200 and 14,800 rpm gave the maximum corrected shaft horsepower. Deterioration in engine performance was noted during the first 20 hours of operation, but further operating time had no significant effect on performance. A change of turbine assembly had a marked effect on performance.

Maximum windmilling speeds were obtained at a propeller-blade angle of approximately 24° at all airspeeds investigated. Data at altitudes of 15,000 and 35,000 feet indicate that windmilling speeds in excess of rated speed would occur at a true airspeed above 218 knots. Modification of the fuel system to provide fuel flows during starting that were lower than those obtainable with the standard fuel system resulted in a significant increase in the range of altitude and windmilling speed at which ignition could be obtained.

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National Advisory Committee for Aeronautics
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APPENDIX A

SYMBOLS

The following symbols are used in this report:

A	cross-sectional area, sq ft
F_j	jet thrust, lb
g	acceleration due to gravity, 32.2 ft/sec^2
ghp	reduction gear loss, horsepower
hp	horsepower
h	enthalpy, Btu/lb
J	mechanical equivalent of heat, 778 ft-lb/Btu
M	Mach number
N	engine speed, rpm
P	total pressure, lb/sq ft abs
p	static pressure, lb/sq ft abs
Q	torque measured by torquemeter, ft-lb
R	gas constant, 53.4 ft-lb/(lb)($^{\circ}$R)
sfc	specific fuel consumption, lb fuel/hr/shp
shp	shaft horsepower
TMhp	torquemeter horsepower
T	total temperature, $^{\circ}$R
V	velocity, ft/sec
W_a	air flow, lb/sec
$W_{a,ctl}$	air-flow leakage from compressor and turbine bearing labryinth, lb/sec
$W_{a,B}$	air-flow leakage from burner-dome rings and cross-over tubes, lb/sec
$W_{a,RB}$	turbine rear-bearing cooling-air flow, lb/sec

W_f	fuel flow, lb/hr
W_g	gas flow, lb/sec
γ	ratio of specific heats
δ	ratio of compressor-inlet total pressure to static pressure of NACA standard atmosphere at sea level
η	efficiency
θ	ratio of compressor-inlet absolute total temperature to static temperature of NACA standard atmosphere at sea level

Subscripts:

c	compressor
j	jet
t	turbine
0	tunnel test-section airstream
1	cowl inlet
2	compressor inlet
3	compressor outlet or combustion-chamber inlet
4	turbine inlet or combustion-chamber outlet
5	turbine outlet
6	exhaust nozzle

The data are generalized to NACA standard sea-level conditions by the following parameters:

F_j/δ	corrected jet thrust, lb
$hp/\delta\sqrt{\theta}$	corrected horsepower
$N/\sqrt{\theta}$	corrected engine speed, rpm
T_4/θ	corrected turbine-inlet temperature, $^{\circ}R$
$W_a\sqrt{\theta}/\delta$	corrected air flow, lb/sec
$W_f/\delta\sqrt{\theta}$	corrected fuel flow, lb/hr

APPENDIX B

METHODS OF CALCULATION

Shaft horsepower. - The torque, as measured by the torquemeter, together with the measured engine speed was used to determine the torquemeter horsepower as follows:

$$\mathrm{TMhp} = \frac{2\pi NQ}{33,000}$$

The shaft horsepower was determined from the torquemeter horsepower by subtracting the gearbox losses

$$\mathrm{shp} = \mathrm{TMhp} - \mathrm{ghp}$$

where ghp was obtained from calibration curves supplied by the engine manufacturer.

Air flow. - Air flow was determined from pressure and temperature measurements in the engine-inlet-air duct (station 1) by use of the equation

$$W_{a,1} = A_1 \sqrt{\frac{2g}{R}} \frac{p_1}{\sqrt{T_1}} \sqrt{\left(\frac{\gamma_1}{\gamma_1 - 1}\right)\left(\frac{P_1}{p_1}\right)^{\frac{\gamma_1 - 1}{\gamma_1}}\left[\left(\frac{P_1}{p_1}\right)^{\frac{\gamma_1 - 1}{\gamma_1}} - 1\right]}$$

Air leakages occurring in various sections of the power section were measured when possible or were assumed to be a percentage of inlet-air flow. Leakage from the compressor rear-bearing labyrinth and the turbine front-bearing labyrinth $W_{a,ctl}$ was measured and found to be approximately 1 percent of $W_{a,1}$. Leakage from the burner-dome rings and cross-over tubes $W_{a,B}$ was assumed to be 1/4 of 1 percent of $W_{a,1}$. The gas flow through the turbine would be determined as

$$W_{g,4} = W_{a,1} - W_{a,ctl} - 0.0025W_{a,1} + \frac{W_f}{3600}$$

Cooling of the rear turbine bearing is augmented by air coming from ambient conditions through the bearing supports to the bearing and discharging into the gas stream. This inflow $W_{a,RB}$ was found to be 1/2 of 1 percent of $W_{a,1}$. Thus, the exhaust-nozzle gas flow is obtained by

$$W_{g,6} = W_{g,4} + 0.005W_{a,1}$$

Temperatures. - Stagnation temperatures obtained from thermocouples were assumed equal to the indicated values except at the exhaust nozzle, where a recovery factor of 0.85 was applied. The turbine-inlet temperature was calculated by assuming the turbine power to be equal to the sum of the compressor absorbed power and the torquemeter horsepower. Thus,

$$W_{g,4}(h_4 - h_6) = W_{a,1}(h_3 - h_2) + \frac{550}{J}\,(\mathrm{TMhp})$$

Then, use of enthalpy charts determined the turbine-inlet temperature (see ref. 2).

Jet thrust. - Jet thrust was determined from

$$F_j = \frac{W_{g,6}}{g} V_j = \frac{W_{g,6}}{g}\sqrt{\frac{2\gamma_6 Rg}{\gamma_6 - 1}\,\frac{T_6}{\left(\frac{P_6}{p_0}\right)^{\frac{\gamma_6 - 1}{\gamma_6}}}\left[\left(\frac{P_6}{p_0}\right)^{\frac{\gamma_6 - 1}{\gamma_6}} - 1\right]}$$

REFERENCES

1. Meyer, Carl L., and Johnson, LaVern A.: Performance and Operational Characteristics of a Python Turbine-Propeller Engine at Simulated Altitude Conditions. NACA RM E51I14, 1952.

2. Turner, L. Richard, and Bogart, Donald: Constant-Pressure Combustion Charts Including Effects of Diluent Addition. NACA Rep. 937, 1949. (Supersedes NACA TN's 1086 and 1655.)

TABLE I. - PERFORMANCE DATA FOR XT38-A-2 TURBOPROP ENGINE

Run	Altitude, ft	Tunnel static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Engine-inlet total temperature, T_1, ^oR	Simulated flight Mach number, M_0	Engine speed, N, rpm	Shaft horsepower, shp	Engine fuel flow, W_f, lb/hr	Specific fuel consumption, sfc, lb/hr/shp	Engine air flow, $W_{a,1}$, lb/sec	Turbine-inlet total temperature, T_4, ^oR	Exhaust-nozzle total temperature, T_6, ^oR	Jet thrust, F_j, lb	Corrected engine speed, $N/\sqrt{\theta}$, rpm	Corrected shaft horsepower, $shp/\delta_2\sqrt{\theta_2}$	Corrected fuel flow, $W_f/\delta_2\sqrt{\theta_2}$, lb/hr	Corrected air flow, $W_{a,1}\sqrt{\theta_2}/\delta_2$, lb/sec	Corrected turbine-inlet temperature, T_4/θ_2, ^oR	Corrected jet thrust, F_j/δ_2, lb
1	5,000	1754	1863	539	0.295	14,894	667	882	1.322	25.39	1670	1163	451	14,617	744	983	29.40	1609	512
2		1753	1867	542	.302		177	696	3.932	25.57	1520	1071	402	14,575	196	772	29.61	1456	455
3		1755	1865	541	.297		2	645	322.5	25.58	1470	1040	381	14,587	2	717	29.65	1411	432
4		1758	1870	542	.299	14,602	1695	1270	.749	25.02	1963	1360	457	14,290	1878	1407	28.95	1880	517
5		1757	1869	542	.299		1383	1140	.824	25.02	1870	1300	448	14,290	1532	1263	28.95	1791	507
6		1759	1873	540	.302		1086	1025	.944	25.10	1773	1230	443	14,316	1203	1136	28.94	1705	501
7		1754	1869	539	.303		810	918	1.133	25.09	1690	1180	440	14,330	900	1020	28.95	1628	498
8		1758	1871	540	.299	14,310	1957	1370	.700	24.98	2023	1406	466	14,030	2170	1519	28.83	1945	527
9		1756	1861	541	.290		73	611	8.356	24.76	1450	1037	358	14,015	81	680	28.75	1392	407
10		1765	1875	536	.295		569	801	1.408	25.23	1593	1119	430	14,081	632	890	28.94	1544	485
11		1762	1874	540	.299		841	902	1.073	24.43	1690	1186	422	14,030	931	999	28.14	1625	476
12		1765	1881	544	.303		1256	1075	.856	24.73	1813	1268	460	13,977	1380	1181	28.49	1730	518
13		1761	1871	541	.295		1641	1245	.759	24.62	1950	1355	440	14,015	1818	1379	28.44	1871	498
14		1754	1863	470	.295		2568	1596	.622	27.90	2007	1371	598	15,040	3066	1906	30.16	2216	679
15		1763	1879	464	.303		12	623	51.92	28.53	1315	913	409	15,140	14	742	30.38	1471	461
16		1766	1872	468	.290		763	886	1.161	28.14	1503	1031	482	15,068	908	1054	30.19	1667	545
17		1763	1873	473	.295		1305	1082	.829	28.11	1655	1131	490	14,983	1544	1280	30.33	1816	554
18		----	1845	469	-----		2057	1397	.679	-----	----	----	---	15,054	2483	1686	-----	----	---
19		1758	1866	451	.292		2224	1469	.661	28.96	1870	1272	576	15,355	2707	1788	30.61	2152	653
20		1757	1867	449	.297		2725	1676	.615	29.02	2000	1358	625	15,383	3319	2041	30.59	2312	708
21		1762	1871	446	.295		1741	1285	.738	29.27	1730	1174	524	15,440	2124	1568	30.67	2013	593
22		1761	1869	445	.292		1032	1015	.984	29.29	1543	1049	504	15,455	1262	1241	30.70	1799	571
23		1767	1875	446	.292		56	656	11.71	29.43	1306	900	431	15,440	68	799	30.81	1520	487
24		1761	1871	448	.295		530	821	1.549	29.22	1420	969	591	15,398	645	999	30.71	1645	555
25		1754	1867	545	.295	14,018	1913	1348	.705	25.90	2038	1443	480	13,680	2116	1491	30.07	1939	544
26		1759	1868	536	.299		73	590	8.082	24.26	1428	1021	341	13,794	81	658	27.92	1384	384
27		1757	1869	541	.295		532	755	1.419	23.91	1573	1121	393	13,729	590	837	27.64	1510	445
28		1762	1875	540	.299		836	882	1.055	23.84	1673	1184	406	13,743	925	976	27.46	1609	458
29		1757	1871	537	.302		1197	1033	.863	24.13	1793	1257	417	13,781	1331	1149	27.75	1734	472
30		1759	1874	541	.302		1542	1175	.762	23.95	1910	1338	418	13,729	1705	1300	27.61	1833	472
31		1757	1874	541	.306	13,726	1890	1307	.692	23.10	2033	1433	410	13,443	2090	1446	26.63	1951	463
32		1759	1878	539	.308		29	539	18.59	23.53	1407	1010	317	13,471	32	596	27.01	1355	357
33		1757	1873	540	.303		430	692	1.609	23.36	1533	1093	364	13,457	476	767	26.93	1474	411
34		1756	1873	542	.306		905	892	.986	23.18	1700	1202	392	13,432	1001	987	26.77	1628	443
35		1759	1876	543	.306		1386	1099	.793	23.07	1870	1321	394	13,420	1529	1212	26.62	1786	444
36		1760	1880	544	.308	13,434	1836	1293	.704	22.18	2047	1456	389	13,121	2020	1422	25.57	1951	438
37		1760	1878	543	.306		1424	1109	.779	22.30	1900	1349	376	13,134	1569	1222	25.71	1815	424
38		1759	1876	542	.306		1029	935	.909	22.32	1753	1250	372	13,147	1136	1032	25.73	1679	420
39		1759	1878	542	.308		484	699	1.444	22.60	1535	1111	348	13,147	534	771	26.04	1470	392
40		1762	1882	540	.308		24	518	21.58	23.02	1393	1006	302	13,171	26	571	26.38	1339	339
41		1758	1881	544	.312	13,142	1759	1259	.716	21.26	2055	1472	368	12,836	1933	1384	24.49	1959	414
42		1754	1873	545	.308		1343	1060	.789	21.19	----	1355	---	12,825	1481	1169	24.53	----	---
43		1755	1876	544	.311		970	900	.928	21.36	1747	1256	350	12,836	1069	992	24.67	1665	395
44		1758	1879	542	.311		547	709	1.296	21.69	1570	1136	324	12,861	603	781	24.97	1504	365
45	15,000	1187	1265	475	.303	14,894	84	455	5.417	19.39	1380	948	296	15,564	147	795	31.04	1508	495
46		1184	1261	474	.302		352	551	1.565	19.37	1470	1001	321	15,579	618	967	31.07	1609	539
47		1186	1260	475	.295		649	665	1.025	19.46	1580	1074	351	15,564	1139	1167	31.25	1726	589
48		1182	1258	475	.299		818	730	.892	19.44	1650	1113	357	15,564	1438	1283	31.28	1803	600
49		1186	1261	476	.297		1168	880	.753	19.44	1797	1216	379	15,549	2046	1542	31.24	1959	636

TABLE I. - Continued. PERFORMANCE DATA FOR XT38-A-2 TURBOPROP ENGINE

Run	Altitude, ft	Tunnel static pressure, P_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Simulated flight Mach number, M_0	Engine speed, N, rpm	Shaft horsepower, shp	Engine fuel flow, W_f, lb/hr	Specific fuel consumption, sfc, lb/hr/shp	Engine air flow, $W_{a,1}$, lb/sec	Turbine-inlet total temperature, T_4, °R	Exhaust-nozzle total temperature, T_6, °R	Jet thrust, F_j, lb	Corrected engine speed, $N/\sqrt{\theta}$, rpm	Corrected shaft horsepower, $shp/\delta_2\sqrt{\theta_2}$	Corrected fuel flow, $W_f/\delta_2\sqrt{\theta_2}$, lb/hr	Corrected air flow, $W_{a,1}\sqrt{\theta_2}/\delta_2$, lb/sec	Corrected turbine-inlet temperature, T_4/θ_2, °R	Corrected jet thrust, F_j/δ_2, lb
50	15,000	1191	1266	475	0.297	14,602	31	410	13.23	19.29	1335	915	286	15,259	54	716	30.84	1458	478
51		1185	1264	475	.306		514	605	1.177	19.27	1523	1036	339	15,259	899	1058	30.87	1664	567
52		1187	1264	476	.302		819	710	.867	19.25	1620	1098	348	15,244	1432	1241	30.86	1766	583
53		1185	1261	473	.299		1100	828	.753	19.28	1747	1173	362	15,288	1933	1455	30.89	1917	607
54		1187	1265	473	.303		1377	946	.687	19.31	1857	1261	390	15,288	2413	1657	30.84	2037	652
55		1183	1259	476	.311		1679	1082	.644	19.08	1997	1356	418	15,244	2947	1899	30.72	2177	703
56		1179	1258	475	.306	14,310	201	473	2.353	18.89	1377	945	289	14,954	353	832	30.39	1504	486
57		1183	1261	473	.303		381	536	1.407	19.05	1443	989	312	14,983	669	942	30.52	1583	524
58		1190	1266	471	.299		1196	876	.732	19.25	1775	1209	369	15,026	2099	1537	30.65	1956	617
59		1189	1264	472	.297		1505	1000	.665	19.22	1903	1302	397	15,011	2641	1756	30.68	2092	665
60		1190	1267	475	.302		1712	1089	.636	18.95	1993	1356	416	14,954	2987	1900	30.28	2177	695
61		1195	1271	472	.299		755	684	.906	19.26	1593	1083	341	15,011	1319	1195	30.58	1752	568
62		1186	1263	473	.302	14,018	78	397	5.090	18.72	1307	901	270	14,677	137	696	29.93	1434	452
63		1187	1264	473	.302		485	547	1.128	18.74	1455	989	309	14,677	850	959	29.95	1596	517
64		1188	1264	474	.299		1027	771	.7507	18.74	1680	1145	341	14,663	1798	1350	29.98	1839	571
65		1192	1269	475	.302		1245	873	.7012	18.74	1790	1228	359	14,649	2169	1521	29.92	1952	598
66		1187	1263	475	.299		1555	1011	.6502	18.69	1937	1327	386	14,649	2721	1769	29.94	2116	647
67		1187	1264	476	.302		1755	1095	.6239	18.68	2020	1385	408	14,635	3068	1914	29.94	2202	683
68		1179	1258	478	.306	13,726	1633	1068	.6540	18.14	2003	1390	392	14,302	2863	1872	29.28	2175	659
69		1190	1270	475	.306		221	432	1.955	18.52	1340	925	273	14,344	385	752	29.52	1464	455
70		1189	1267	477	.303		622	600	.9646	18.34	1527	1036	309	14,316	1084	1045	29.36	1661	516
71		1190	1268	475	.303		853	696	.8159	18.50	1603	1099	315	14,344	1488	1214	29.54	1751	526
72		1187	1265	476	.303		1188	837	.7045	18.34	1763	1210	340	14,330	2075	1462	29.38	1922	569
73		1189	1266	477	.302		1354	921	.6802	18.44	1850	1274	359	14,316	2360	1605	29.54	2013	600
74		1187	1267	478	.306	13,434	278	447	1.608	18.20	1360	945	269	13,998	484	778	29.17	1477	449
75		1184	1263	478	.306		677	614	.9069	17.82	1530	1056	297	13,998	1181	1071	28.64	1661	497
76		1188	1264	477	.299		1070	777	.7262	17.96	1703	1173	320	14,012	1868	1357	28.83	1853	536
77		1188	1265	477	.302		1395	930	.6667	17.97	1863	1291	350	14,012	2434	1623	28.82	2027	586
78		1189	1266	476	.302		1738	1088	.6260	18.11	2037	1409	387	14,025	3033	1899	28.98	2221	647
79		1190	1270	483	.306	13,142	1675	1050	.627	17.03	2037	1425	355	13,628	2892	1814	27.37	2189	591
80		1183	1262	478	.306		1492	957	.6414	17.19	1943	1354	340	13,694	2607	1672	27.66	2110	570
81		1193	1271	476	.302		1308	876	.6697	17.54	1813	1265	327	13,720	2273	1522	27.98	1977	544
82		1189	1268	480	.303		843	670	.7948	17.45	1600	1116	295	13,668	1463	1163	28.01	1730	492
83		1184	1267	480	.312		412	483	1.172	17.43	1410	985	267	13,068	716	839	27.99	1524	446
84	25,000	778	819	441	.273	14,894	706	633	.897	13.29	1829	1247	256	16,160	1980	1775	31.66	2153	662
85		774	817	442	.280		878	689	.785	13.13	1918	1310	276	16,145	2465	1935	31.55	2252	715
86		763	808	439	.287		109	398	3.651	13.10	1472	1018	229	16,190	310	1133	31.56	1740	600
87		781	825	440	.280		266	453	1.703	13.22	1555	1069	238	16,175	741	1262	31.23	1834	610
88		773	816	441	.280		481	527	1.096	13.15	1670	1144	238	16,160	1353	1482	31.43	1965	617
89		768	813	441	.287		554	563	1.016	13.11	1720	1174	241	16,160	1564	1590	31.45	2024	627
90		771	818	439	.292	14,602	863	671	.777	13.08	1894	1290	277	15,872	2427	1887	31.12	2239	717
91		780	826	440	.287		638	579	.908	13.13	1748	1190	238	15,858	1775	1611	30.97	2062	610
92		771	820	440	.299		431	498	1.155	13.07	1620	1104	228	15,858	1208	1395	31.05	1911	588
93		773	821	430	.295		187	414	2.214	13.36	1478	1012	228	16,048	530	1172	31.34	1784	588
94		770	820	440	.302		21	349	16.62	13.09	1404	969	224	15,858	59	978	31.10	1656	578
95		775	825	436	.302	14,310	1025	739	.721	13.19	1975	1349	293	15,612	2868	2068	31.01	2351	752
96		774	821	432	.292		122	381	3.123	13.10	1434	991	221	15,684	345	1076	30.80	1723	570
97		775	825	436	.302		385	474	1.231	13.19	1578	1081	225	15,612	1077	1326	31.01	1879	577
98		776	825	435	.297		705	584	.828	13.07	1755	1192	236	15,627	1975	1636	30.69	2094	605
99		770	816	441	.290		930	689	.741	12.80	1925	1317	271	15,526	2616	1938	30.59	2266	703

TABLE I. - Continued. PERFORMANCE DATA FOR XT38-A-2 TURBOPROP ENGINE

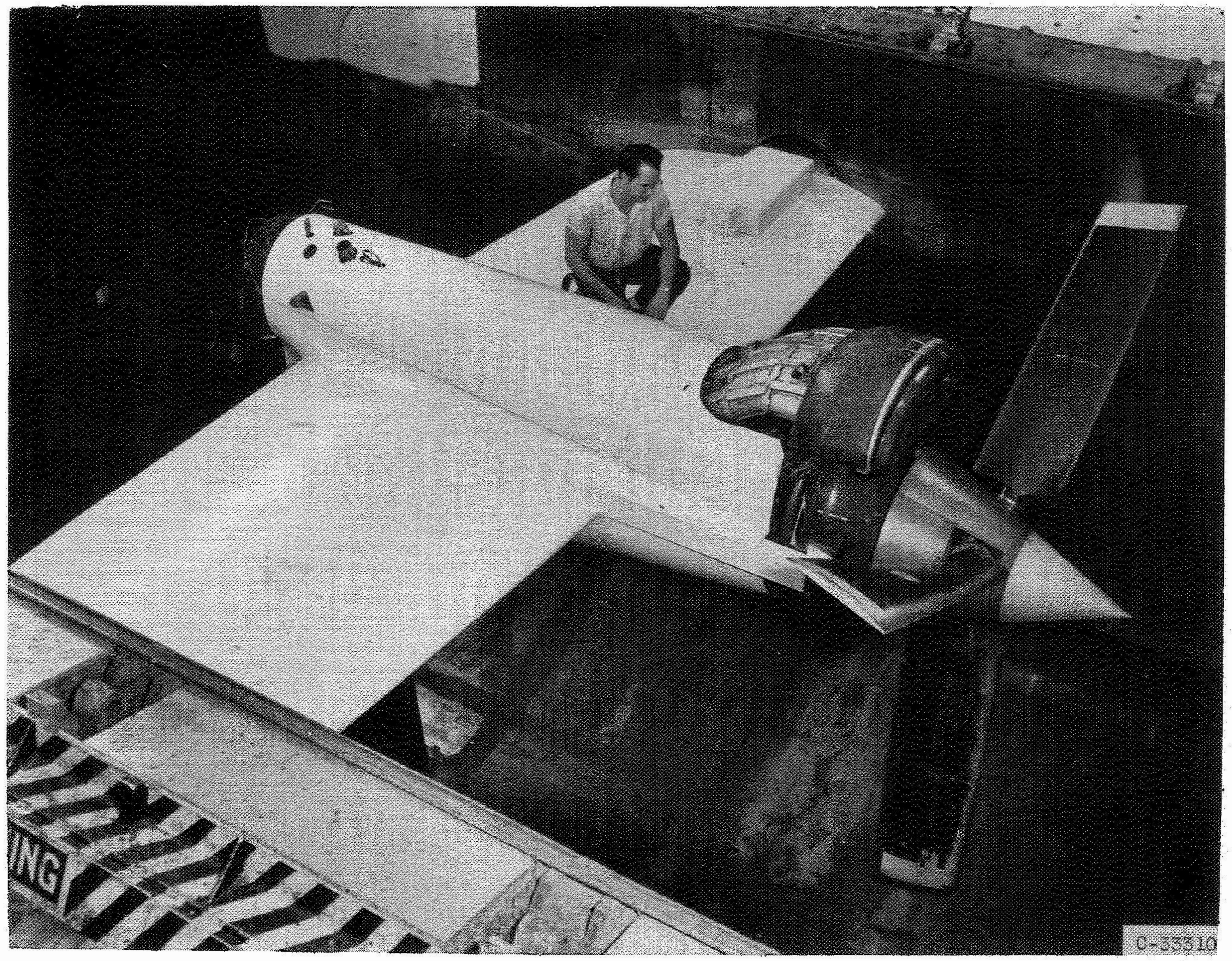
Run	Altitude, ft	Tunnel static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Simulated flight Mach number, M_0	Engine speed, N, rpm	Shaft horsepower, shp	Engine fuel flow, W_f, lb/hr	Specific fuel consumption, sfc, lb/hr/shp	Engine air flow, $W_{a,1}$, lb/sec	Turbine-inlet total temperature, T_4, °R	Exhaust-nozzle total temperature, T_6, °R	Jet thrust, F_j, lb	Corrected engine speed, $N/\sqrt{\theta}$, rpm	Corrected shaft horsepower, $shp/\delta_2\sqrt{\theta_2}$	Corrected fuel flow, $W_f/\delta_2\sqrt{\theta_2}$, lb/hr	Corrected air flow, $W_{a,1}\sqrt{\theta_2}/\delta_2$, lb/sec	Corrected turbine-inlet temperature, T_4/θ_2, °R	Corrected jet thrust, F_j/δ_2, lb
100	25,000	774	823	437	0.297	14,018	1116	765	0.686	12.92	2010	1376	285	15,280	3127	2144	30.48	2387	733
101		770	816	433	.290		939	669	.713	13.05	1875	1282	274	15,350	2666	1899	30.90	2247	710
102		773	823	433	.302		816	619	.757	13.09	1788	1221	253	15,350	2297	1742	30.74	2143	650
103		780	829	433	.297		585	533	.911	13.14	1647	1124	230	15,350	1634	1489	30.63	1974	587
104		776	824	433	.295		344	444	1.291	13.10	1515	1040	219	15,350	967	1249	30.73	1816	562
105		775	824	434	.297		107	358	3.346	13.08	1385	958	216	15,336	301	1006	30.71	1657	555
106		775	821	431	.287	13,726	1101	748	.679	12.87	1970	1357	280	15,057	3113	2115	30.22	2372	722
107		773	820	436	.292		930	660	.710	12.67	1870	1284	261	14,975	2618	1858	29.96	2226	673
108		775	824	436	.297		709	564	.796	12.70	1710	1170	219	14,975	1987	1580	29.90	2036	562
109		771	820	435	.299		422	459	1.088	12.68	1537	1057	211	14,989	1189	1293	29.95	1834	544
110		770	821	435	.303		170	362	2.129	12.69	1390	963	212	14,989	478	1019	29.94	1659	546
111		778	826	441	.295	13,434	468	465	.993	12.53	1537	1059	206	14,576	1301	1601	29.60	1809	528
112		773	822	435	.297		727	565	.777	12.57	1693	1162	217	14,670	2044	1588	29.61	2020	559
113		776	824	438	.295		913	646	.708	12.55	1840	1266	248	14,630	2554	1807	29.61	2181	637
114		777	824	437	.290		182	364	2.000	12.45	1393	970	214	14,643	509	1019	29.33	1654	550
115	35,000	486	519	435	.308	14,894	135	328	2.430	8.42	1590	1100	155	16,264	601	1460	31.42	1897	632
116		487	520	435	.308		335	400	1.194	8.42	1770	1218	162	16,264	1488	1777	31.36	2112	659
117		484	516	435	.303		412	435	1.056	8.39	1860	1281	175	16,264	1845	1948	31.50	2219	718
118		488	520	433	.303		71	302	4.254	8.44	1543	1070	149	16,309	316	1346	31.37	1849	606
119		482	513	444	.299		499	454	.909	8.28	1947	1339	181	16,100	2225	2024	31.59	2276	747
120		490	520	438	.292		372	401	1.078	8.39	1808	1234	159	16,220	1648	1777	31.36	2143	647
121		484	514	438	.295		254	351	1.382	8.35	1683	1166	153	16,220	1139	1574	31.58	1995	630
122		487	519	439	.303		112	304	2.714	8.39	1568	1067	149	16,190	496	1347	31.46	1854	607
123		485	516	438	.299		19	270	14.21	8.25	1490	1040	145	16,220	85	1206	31.08	1766	595
124		480	512	436	.306	14,602	512	460	.898	8.23	1937	1337	190	15,931	2309	2074	31.18	2306	785
125		479	512	436	.311		601	500	.832	8.35	2030	1405	206	15,931	2710	2255	31.63	2417	851
126		485	518	436	.308		357	400	1.120	8.40	1780	1234	168	15,931	1591	1783	31.45	2119	686
127		485	517	437	.303		263	363	1.380	8.27	1693	1173	158	15,916	1173	1619	31.06	2011	647
128		486	516	436	.295		77	295	3.831	8.38	1520	1058	155	15,931	344	1320	31.50	1810	636
129		485	515	442	.295		11	255	23.18	8.09	1468	1021	142	15,829	49	1136	30.68	1724	583
130		485	518	434	.308	14,310	675	537	.796	8.29	2083	1451	210	15,655	3017	2400	30.96	2491	858
131		487	517	437	.295		23	262	11.39	8.16	1443	1009	141	15,598	103	1169	30.65	1714	577
132		484	516	437	.303		163	315	1.933	8.14	1570	1089	142	15,598	729	1408	30.63	1865	582
133		482	515	440	.308		185	367	1.984	8.10	1667	1180	148	15,541	825	1638	30.65	1966	608
134		488	520	434	.303		454	427	.941	8.32	1843	1272	172	15,655	2021	1901	30.96	2204	700
135		480	512	435	.306		548	466	.850	8.13	1953	1350	190	15,627	2473	2103	30.76	2330	785
136		484	514	441	.295		12	242	20.17	8.10	1423	995	140	15,526	54	1081	30.74	1675	576
137		486	519	434	.308	14,018	713	539	.7560	8.20	2103	1467	209	15,336	3180	2404	30.57	2515	852
138		487	519	434	.303		578	474	.8201	8.19	1957	1362	191	15,336	2578	2114	30.53	2341	779
139		486	516	434	.295		466	423	.9077	8.17	1837	1274	169	15,336	2090	1898	30.64	2197	693
140		487	518	432	.299		265	346	1.306	8.09	1627	1142	150	15,364	1186	1549	30.15	1954	613
141		486	518	440	.303		152	275	1.809	8.13	1503	1044	139	15,224	674	1220	30.58	1773	568
142		485	516	439	.299		12	235	19.58	8.01	1390	976	134	15,238	53	1048	30.21	1643	550
143		486	516	435	.295	13,726	95	271	2.853	8.05	1460	1025	133	14,989	425	1214	30.22	1742	545
144		490	522	434	.302		226	323	1.429	8.09	1577	1101	140	15,016	1002	1433	29.99	1886	568
145		484	515	437	.299		350	363	1.037	7.90	1700	1181	142	14,961	1568	1626	29.78	2019	583
146		491	523	435	.302		587	466	.794	8.10	1933	1343	182	14,989	2593	2059	30.00	2306	736
147		490	522	435	.302		676	508	.752	8.09	2048	1428	194	14,989	2993	2249	30.02	2444	786
148		484	516	439	.303		12	224	18.67	7.90	1370	959	127	14,920	53	999	29.80	1620	521

TABLE I. - Continued. PERFORMANCE DATA FOR XT38-A-2 TURBOPROP ENGINE

Run	Altitude, ft	Tunnel static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Simulated flight Mach number, M_0	Engine speed, N, rpm	Shaft horsepower, shp	Engine fuel flow, W_f, lb/hr	Specific fuel consumption, sfc, lb/hr/shp	Engine air flow, $W_{a,1}$, lb/sec	Turbine-inlet total temperature, T_4, °R	Exhaust-nozzle total temperature, T_6, °R	Jet thrust, F_j, lb	Corrected engine speed, $N/\sqrt{\theta}$, rpm	Corrected shaft horsepower, $shp/\delta_2\sqrt{\theta_2}$	Corrected fuel flow, $W_f/\delta_2\sqrt{\theta_2}$, lb/hr	Corrected air flow, $W_{a,1}\sqrt{\theta_2}/\delta_2$, lb/sec	Corrected turbine-inlet temperature, T_4/θ_2, °R	Corrected jet thrust, F_j/δ_2, lb
149	35,000	487	519	433	0.302	13,434	552	439	0.795	7.97	1899	1323	174	14,710	2464	1960	29.68	2276	709
150		490	521	435	.297		453	403	.890	7.96	1780	1241	150	14,670	2009	1787	29.60	2124	609
151		489	521	436	.302		338	354	1.047	7.82	1671	1168	141	14,656	1498	1569	29.11	1989	573
152		490	523	438	.306		250	324	1.296	7.83	1588	1113	139	14,630	1102	1428	29.10	1882	562
153		493	524	437	.297		109	269	2.468	7.97	1498	1026	131	14,643	480	1184	29.53	1730	529
154		502	545	435	.346	14,894	471	451	.9575	8.87	1857	1267	193	16,264	1997	1912	31.53	2216	749
155		497	540	434	.348		389	411	1.057	8.72	1775	1211	174	16,294	1668	1762	31.25	2123	682
156		490	535	434	.357		295	376	1.275	8.68	1693	1159	156	16,294	1276	1627	31.39	2025	617
157		493	535	435	.344	14,602	637	514	.8069	8.67	2010	1381	215	15,945	2751	2220	31.39	2398	850
158		493	536	433	.348		512	455	.8887	8.69	1883	1293	196	15,989	2213	1967	31.34	2257	774
159		493	534	432	.340		310	396	1.277	8.69	1730	1201	167	16,004	1346	1720	31.42	2078	662
160		493	539	434	.359	14,310	743	548	.7376	8.71	2070	1427	221	15,655	3191	2354	31.27	2476	868
161		493	538	434	.355		654	506	.7737	8.71	1993	1374	213	15,655	2814	2177	31.32	2384	838
162		493	536	434	.348		507	438	.8639	8.58	1850	1271	187	15,655	2190	1892	30.97	2213	738
163		489	556	440	.432	14,894	11	266	24.18	9.03	1440	992	158	16,175	45	1099	31.65	1698	601
164		489	557	442	.435		126	313	2.484	8.90	1540	1056	159	16,145	519	1286	31.20	1808	604
165		487	558	435	.446		281	369	1.313	9.10	1650	1122	173	16,264	1164	1528	31.60	1969	656
166		488	554	444	.430		420	425	1.012	8.85	1803	1232	191	16,100	1734	1754	31.26	2108	729
167		489	557	443	.435		521	465	.8925	9.11	1890	1289	217	16,130	2143	1913	31.98	2214	824
168		488	555	431	.432	14,602	700	547	.7814	8.993	2047	1407	238	16,018	2928	2288	31.25	2465	907
169		490	561	432	.444		581	487	.8382	9.037	1920	1316	222	16,004	2402	2013	31.10	2306	837
170		483	551	434	.438		437	419	.9588	8.813	1793	1224	194	15,975	1836	1760	30.94	2144	745
171		483	550	432	.435		258	351	1.360	8.937	1623	1110	163	16,004	1088	1480	31.37	1950	627
172		488	557	433	.438		94	287	3.053	9.108	1477	1012	158	15,989	390	1194	31.60	1770	600
173		486	555	438	.440	14,310	762	545	.7152	9.04	2070	1429	233	15,584	3164	2263	31.67	2453	888
174		486	556	438	.443		28	242	8.643	8.82	1385	953	150	15,584	116	1003	30.83	1641	571
175		490	558	437	.435		231	318	1.377	8.97	1547	1058	159	15,598	955	1314	31.22	1837	603
176		486	555	438	.440		380	375	.9868	8.92	1680	1147	170	15,584	1578	1557	31.25	1991	648
177		488	556	438	.435		518	433	.836	8.93	1813	1241	193	15,584	2147	1795	31.22	2149	735
178		489	554	439	.427		630	488	.7746	8.91	1947	1337	209	15,555	2615	2026	31.29	2302	798
179		495	566	446	.442	14,018	809	571	.7058	8.82	2103	1457	232	15,125	3264	2303	30.57	2447	867
180		490	558	446	.435		658	495	.7523	8.64	1970	1362	208	15,125	2693	2026	30.37	2293	789
181		485	553	442	.437		575	453	.7878	8.64	1880	1292	200	15,196	2385	1879	30.51	2208	765
182		485	551	443	.431		410	384	.9366	8.61	1707	1169	167	15,181	1705	1597	30.55	2000	641
183		491	556	445	.425		267	333	1.247	8.63	1590	1096	154	15,139	1097	1369	30.41	1854	586
184		488	556	445	.435		28	239	8.536	8.51	1385	963	142	15,139	115	982	29.99	1615	540
185		485	553	444	.437	13,726	65	244	3.754	8.50	1385	963	139	14,838	269	1009	30.08	1619	532
186		489	561	444	.447		270	328	1.215	8.57	1555	1071	150	14,838	1101	1338	29.90	1818	566
187		491	561	444	.442		452	394	.8717	8.68	1717	1181	169	14,838	1843	1607	30.28	2007	637
188		488	559	446	.444		589	458	.7776	8.53	1887	1302	195	14,810	2405	1870	29.93	2196	738
189		485	557	448	.448		753	535	.7105	8.62	2055	1427	219	14,769	3078	2187	30.43	2381	832
190		487	556	442	.440	13,434	626	467	.7460	8.43	1907	1323	193	14,562	2583	1927	29.61	2239	735
191		488	555	446	.432		491	403	.8208	8.50	1775	1230	175	14,495	2020	1658	30.05	2066	667
192		482	553	438	.447		428	375	.8762	8.56	1680	1159	163	14,630	1783	1563	30.09	1991	624
193		482	550	437	.438		297	331	1.114	8.43	1563	1079	145	14,643	1245	1388	29.76	1856	558
194		493	561	441	.434		50	230	4.600	8.48	1350	936	137	14,576	205	941	29.48	1590	517
195		493	588	437	.509	14,602	780	545	.6987	9.54	2047	1404	263	15,916	3060	2138	31.50	2431	947
196		491	584	438	.504		595	487	.8185	9.64	1883	1289	238	15,902	2347	1921	32.08	2232	862
197		493	585	436	.502		410	404	.9854	9.43	1700	1156	205	15,931	1618	1594	31.26	2024	741
198		490	591	435	.524	14,310	722	529	.7327	9.49	1960	1340	254	15,627	2822	2068	31.10	2339	909
199		488	586	435	.519		638	485	.7602	9.33	1875	1277	230	15,627	2516	1912	30.84	2237	831
200		488	588	435	.524	14,018	877	598	.6819	9.35	2083	1433	262	15,308	3447	2350	30.81	2485	943
201		486	586	435	.524		769	540	.7022	9.33	1983	1357	246	15,308	3032	2129	30.84	2366	888
202		486	576	434	.499		626	474	.7572	9.14	1870	1279	215	15,336	2516	1905	30.71	2237	790

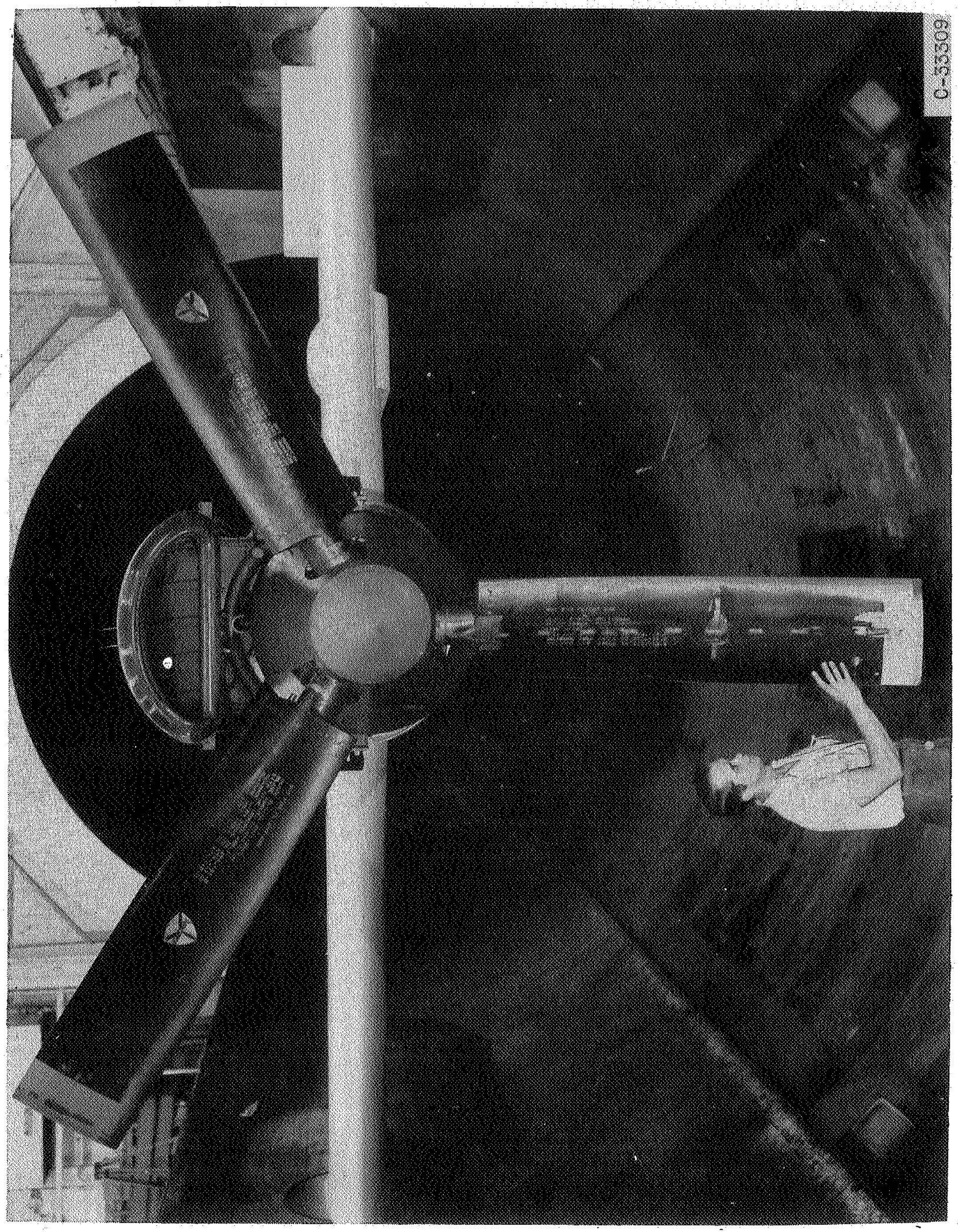
TABLE I. - Concluded. PERFORMANCE DATA FOR XT38-A-2 TURBOPROP ENGINE

Run	Altitude, ft	Tunnel static pressure, P_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Engine-inlet total temperature, T_1, ^oR	Simulated flight Mach number, M_0	Engine speed, N, rpm	Shaft horsepower, shp	Engine fuel flow, W_f, lb/hr	Specific fuel consumption, sfc, lb/hr/shp	Engine air flow, $W_{a,1}$, lb/sec	Turbine-inlet total temperature, T_4, ^oR	Exhaust-nozzle total temperature, T_6, ^oR	Jet thrust, F_j, lb	Corrected engine speed, $N/\sqrt{\theta}$, rpm	Corrected shaft horsepower, $shp/\delta_2\sqrt{\theta_2}$	Corrected fuel flow, $W_f/\delta_2\sqrt{\theta_2}$, lb/hr	Corrected air flow, $W_{a,1}\sqrt{\theta_2}/\delta_2$, lb/sec	Corrected turbine-inlet temperature, T_4/θ_2, ^oR	Corrected jet thrust, F_j/δ_2, lb
203	35,000	487	597	460	0.548	14,894	133	303	2.278	9.29	1500	1023	170	15,817	501	1140	30.99	1693	602
204		487	598	463	.550		285	357	1.253	9.27	1615	1102	180	15,773	1068	1338	30.98	1810	637
205		483	604	455	.574		413	414	1.002	9.85	1727	1174	229	15,907	1545	1549	32.31	1970	802
206		484	604	458	.572		565	478	.8460	9.71	1875	1272	248	15,847	2106	1782	31.96	2125	869
207		479	599	462	.575		641	515	.8034	9.51	1950	1334	256	15,788	2401	1929	31.70	2191	904
208		491	614	453	.575	14,602	769	557	.7243	9.72	2027	1383	262	15,639	2838	2056	29.84	2323	903
209		485	604	456	.569		573	472	.8237	9.51	1850	1263	237	15,580	2142	1764	31.22	2106	830
210		485	602	457	.564		412	398	.9660	9.48	1703	1158	216	15,566	1544	1491	31.27	1934	759
211		485	599	458	.558		276	343	1.243	9.33	1580	1074	175	15,537	1037	1289	30.97	1790	618
212		487	599	460	.552		177	304	1.718	9.30	1503	1025	167	15,507	664	1141	30.93	1696	590
213		488	597	459	.544		6	243	40.50	9.31	1377	946	160	15,522	23	915	31.03	1557	567
214		485	613	436	.589	14,310	900	616	.6844	9.78	2090	1435	295	15,612	3389	2320	30.94	2488	1018
215		484	610	442	.584		889	604	.6794	9.69	2097	1440	287	15,512	3343	2271	31.02	2462	996
216		483	611	444	.590		229	319	1.393	9.67	1500	1017	175	15,469	857	1194	30.97	1754	606
217		489	614	448	.581		386	379	.9819	9.77	1633	1109	202	15,398	1431	1405	31.28	1892	696
218		484	611	444	.587		586	460	.7850	9.67	1809	1228	236	15,469	2194	1722	30.97	2115	817
219		486	614	444	.588		760	545	.7171	9.82	1970	1347	268	15,469	2845	2040	31.30	2303	924
220		485	607	442	.576	14,018	885	599	.6768	9.68	2070	1428	267	15,196	3344	2264	31.14	2431	931
221		490	605	437	.558		12	222	18.500	9.60	1307	895	159	15,280	46	846	30.82	1552	556
222		486	600	437	.558		217	300	1.382	9.32	1450	983	164	15,280	834	1153	30.16	1722	578
223		486	603	437	.564		442	386	.8733	9.34	1640	1115	196	15,280	1691	1476	30.07	1948	688
224		487	604	438	.564		599	455	.7596	9.57	1790	1219	219	15,266	2285	1736	30.80	2121	767
225		490	609	438	.567		758	529	.6979	9.61	1937	1324	244	15,266	2868	2002	30.68	2296	848
226		488	611	457	.576	13,726	832	560	.6731	9.20	2030	1401	247	14,632	3072	2068	29.89	2306	855
227		489	608	458	.567		693	488	.7042	9.18	1900	1304	222	14,604	2566	1807	30.01	2153	773
228		491	608	459	.561		543	418	.7698	9.16	1747	1197	204	14,591	2009	1546	29.98	1975	710
229		491	604	459	.552		337	337	1.000	9.14	1563	1069	166	14,591	1255	1255	30.11	1767	581
230		481	592	459	.553		54	223	4.130	9.15	1337	922	152	14,591	205	847	30.75	1512	543
231		484	603	463	.570	13,434	740	506	.6838	8.72	1960	1355	199	14,226	2750	1880	28.90	2197	698
232		484	601	464	.565		621	445	.7166	8.70	1840	1267	198	14,213	2313	1658	28.96	2058	697
233		484	598	464	.559		417	356	.8537	8.80	1630	1121	169	14,213	1524	1305	28.75	1823	584
234		483	594	464	.552		232	290	1.250	8.77	1371	1021	152	14,213	874	1093	29.54	1534	541
235		482	591	463	.548		25	209	8.360	8.75	1300	905	144	14,226	95	791	29.58	1457	516
236	45,000	293	311	440	.292	14,894	299	280	.9365	5.02	1940	1325	114	16,175	2209	2069	31.45	2288	776
237		300	317	438	.283		21	164	7.810	5.08	1477	1009	95	16,220	153	1192	31.15	1750	634
238		298	315	440	.283		72	180	2.500	5.05	1543	1049	94	16,175	525	1313	31.23	1820	631
239		299	316	439	.283		136	209	1.537	5.07	1640	1114	97	16,190	990	1521	31.22	1939	650
240		296	312	439	.267		184	226	1.228	5.04	1733	1178	99	16,190	1356	1666	31.43	2049	671
241		296	315	440	.299		263	264	1.004	5.17	1850	1259	112	16,175	1919	1926	31.98	2182	752
242		294	311	440	.286	14,602	48	164	3.417	5.03	1493	1019	93	15,858	355	1212	31.51	1761	633
243		293	312	436	.302		125	193	1.544	4.94	1600	1088	94	15,931	925	1428	30.71	1905	638
244		293	310	439	.286		214	233	1.089	5.02	1775	1217	103	15,872	1588	1729	31.52	2099	703
245		298	314	441	.276		258	258	1.000	4.93	1847	1263	102	15,843	1886	1886	30.63	2174	687
246		293	311	440	.292		313	288	.920	5.02	1947	1338	115	15,858	2313	2128	31.45	2296	782
247		295	311	437	.276		366	316	.863	5.04	2047	1413	126	15,916	2714	2343	31.46	2431	857
248		299	316	435	.283	14,310	242	247	1.021	4.98	1793	1228	101	15,627	1770	1806	30.53	2139	676
249		315	313	440	.292		343	288	.840	5.04	1960	1352	114	15,541	2518	2114	31.37	2312	771
250		313	312	440	.292		419	331	.790	5.03	2113	1462	130	15,541	3086	2438	31.41	2492	882
251		313	310	440	.286		264	253	.958	4.78	1863	1282	99	15,541	1957	1875	30.04	2197	676
252		313	310	439	.276		178	213	1.197	4.78	1703	1166	93	15,555	1321	1580	30.01	2013	635
253		314	309	440	.278		123	191	1.553	4.89	1603	1098	92	15,541	915	1420	30.84	1891	630
254		313	309	440	.278		47	158	3.362	5.00	1470	1011	90	15,541	350	1175	31.53	1734	616
255		295	313	441	.292	14,018	161	202	1.255	4.79	1640	1137	91	15,210	1181	1482	29.85	1930	615
256		296	315	438	.299		231	230	.9957	4.95	1737	1193	98	15,266	1690	1682	30.54	2059	658
257		296	312	441	.276		274	254	.9270	4.79	1843	1269	98	15,210	2016	1869	29.95	2169	665
258		294	314	441	.308		338	286	.8462	4.93	1940	1335	113	15,210	2471	2091	30.63	2283	762
259		295	313	442	.292		398	320	.8040	4.92	2067	1439	123	15,196	2917	2345	30.69	2427	831
260		295	311	436	.276		21	148	7.048	4.93	1410	974	84	15,294	156	1099	30.74	1679	572



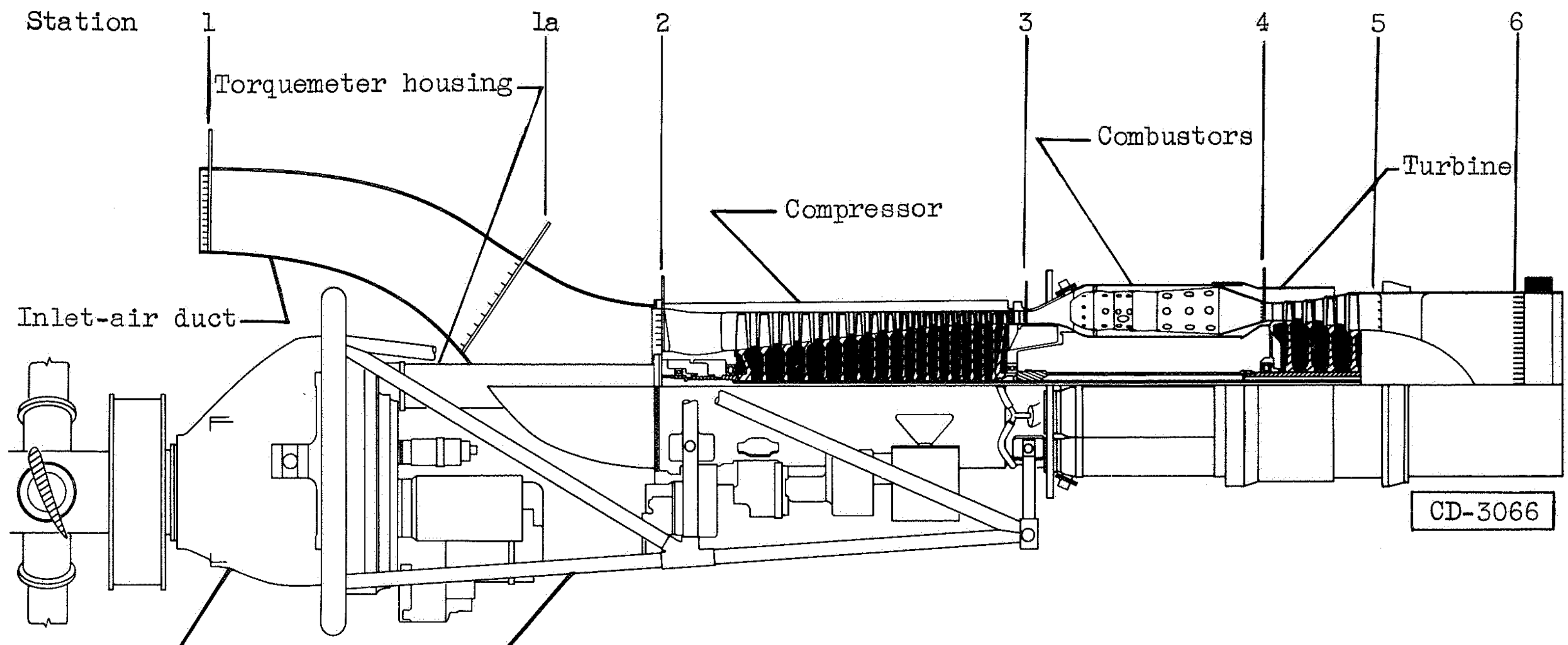
(a) Side view.

Figure 1. - Installation of XT38 turboprop engine in wind tunnel.



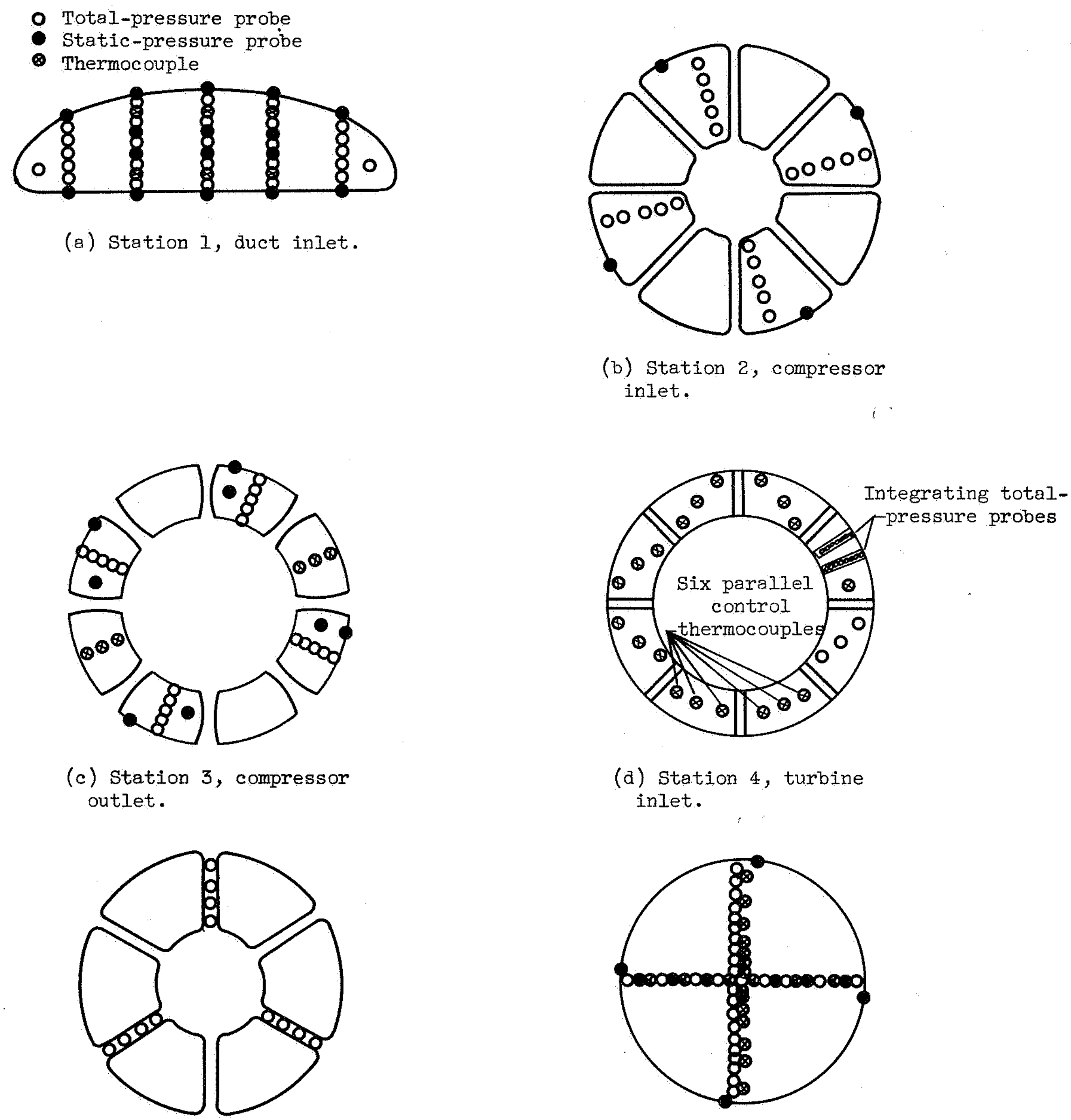
(b) Front view.

Figure 1. - Concluded. Installation of XT38 turboprop engine in wind tunnel.



Probes	Station						
	1	1a	2	3	4	5	6
Thermocouple	6	0	0	6	19	0	20
Static pressure	16	20	4	8	0	0	10
Total pressure	27	27	20	20	5	12	29

Figure 2. - Cross section of turboprop engine showing location of components and measuring stations.



(a) Station 1, duct inlet.

(b) Station 2, compressor inlet.

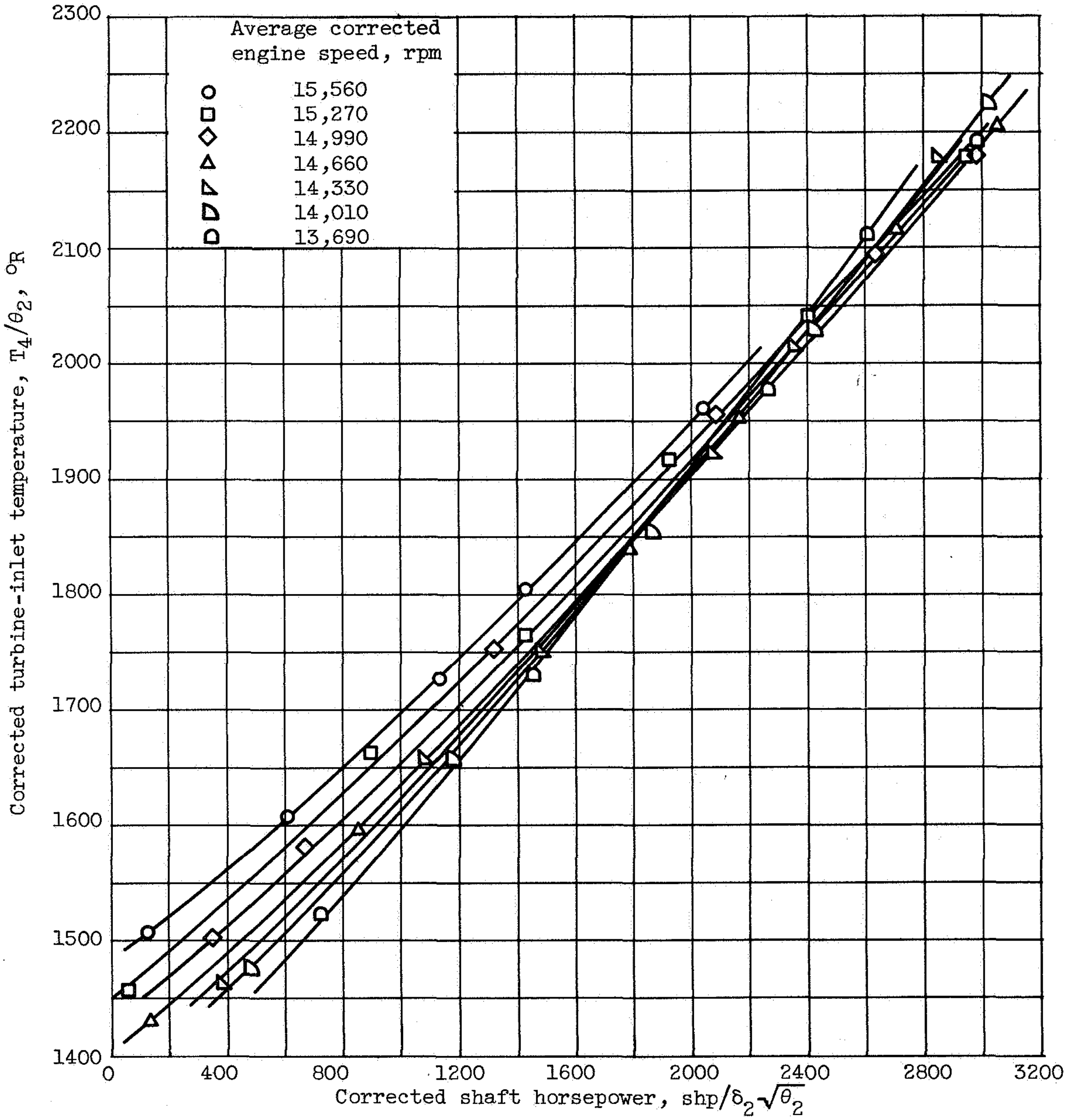
(c) Station 3, compressor outlet.

(d) Station 4, turbine inlet.

(e) Station 5, turbine outlet.

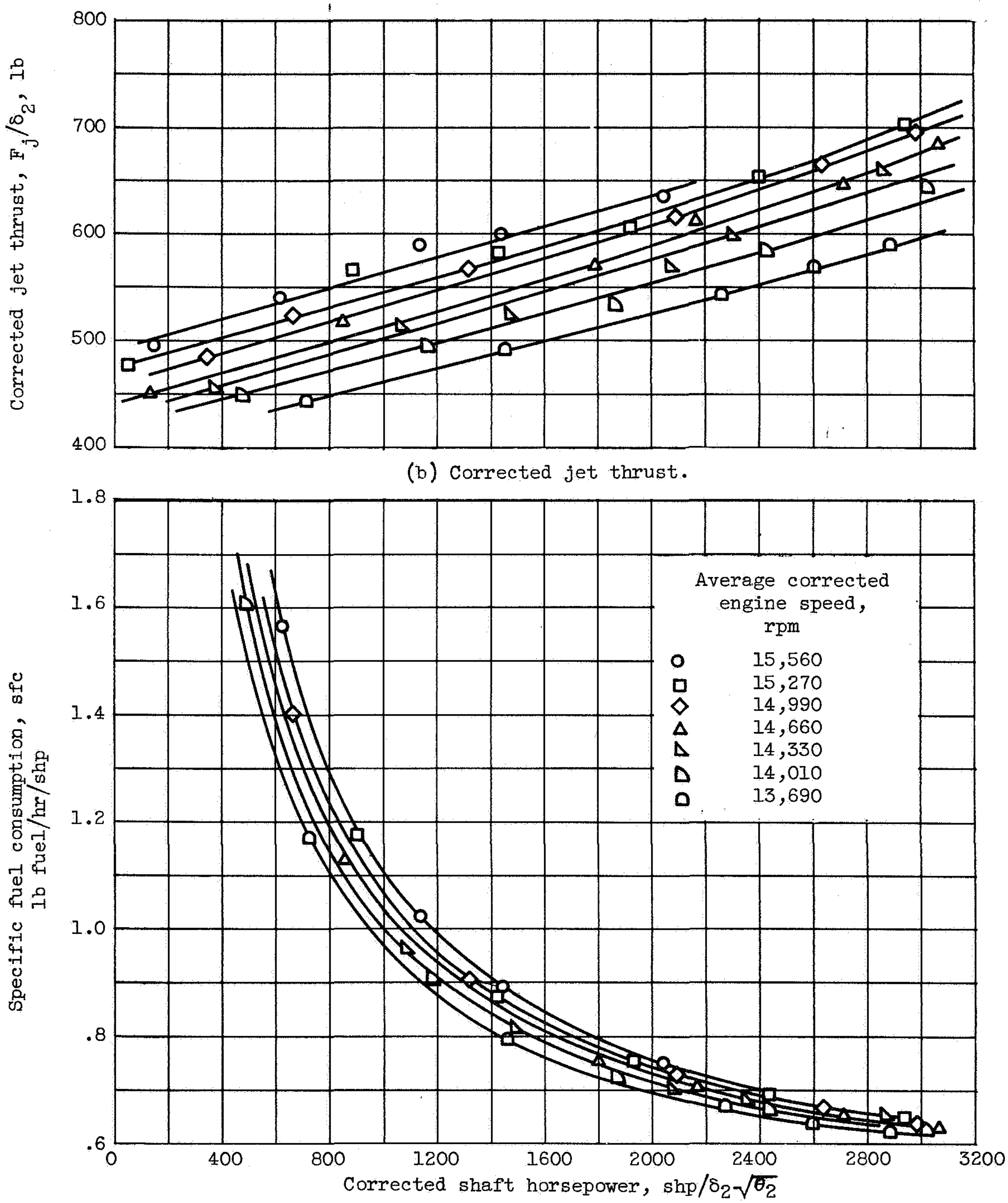
(f) Station 6, exhaust nozzle.

Figure 3. - Schematic diagrams of instrumentation stations viewed from upstream.



(a) Corrected turbine-inlet temperature.

Figure 4. - Effect of corrected shaft horsepower on engine performance at various engine speeds. Altitude, 15,000 feet; flight Mach number, 0.303.



(b) Corrected jet thrust.

(c) Specific fuel consumption.

Figure 4. - Concluded. Effect of corrected shaft horsepower on engine performance at various engine speeds. Altitude, 15,000 feet; flight Mach number, 0.303.

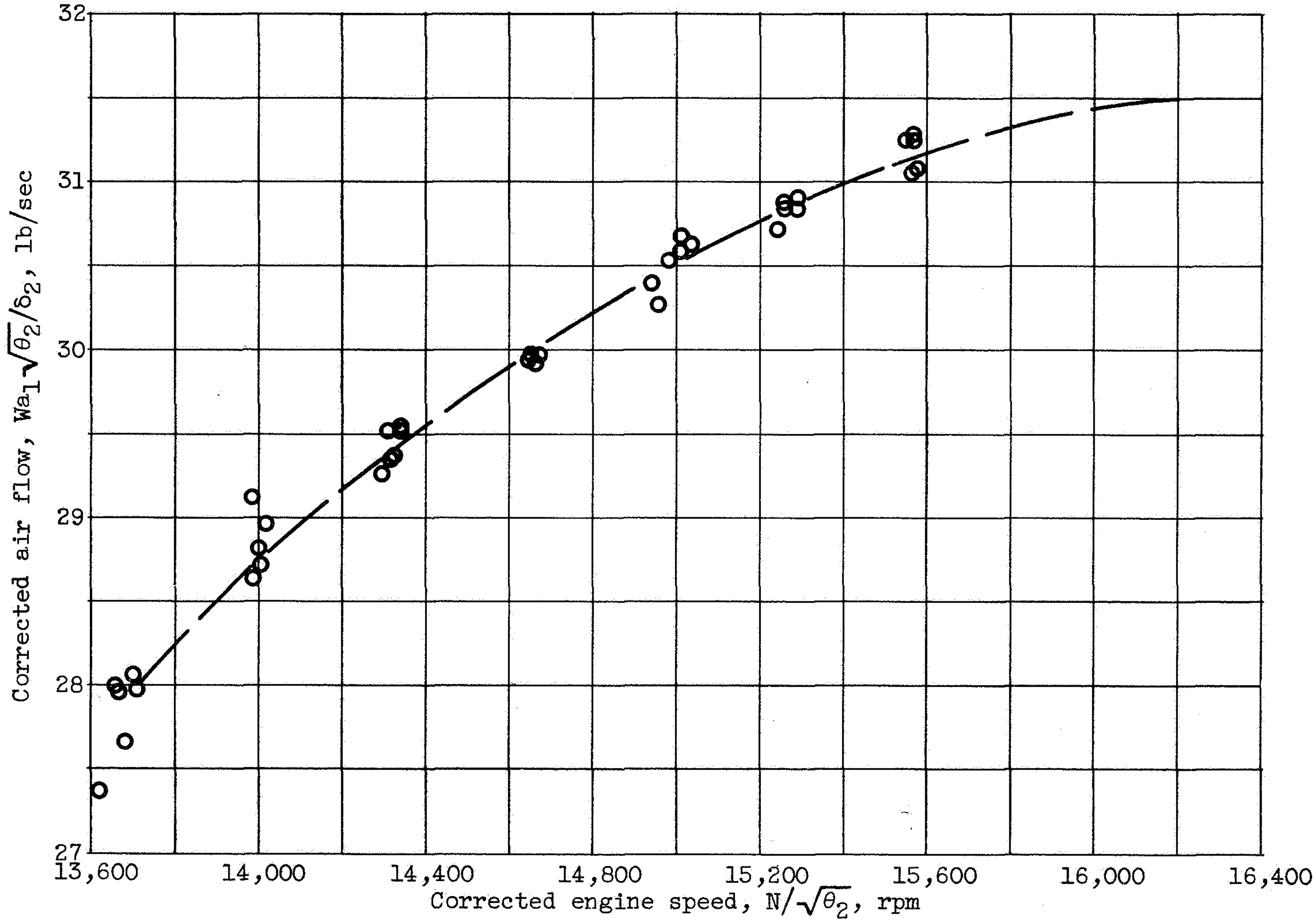
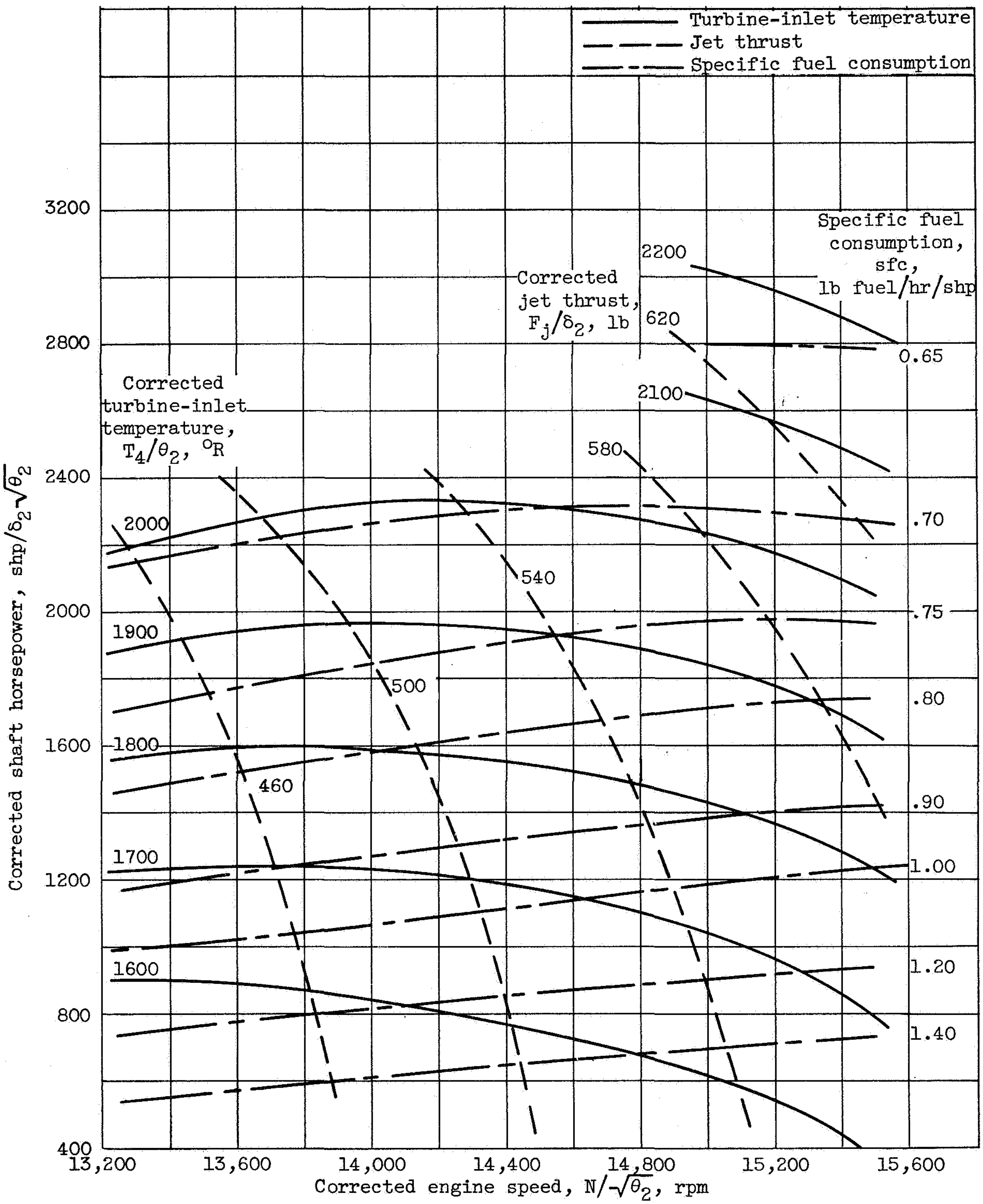
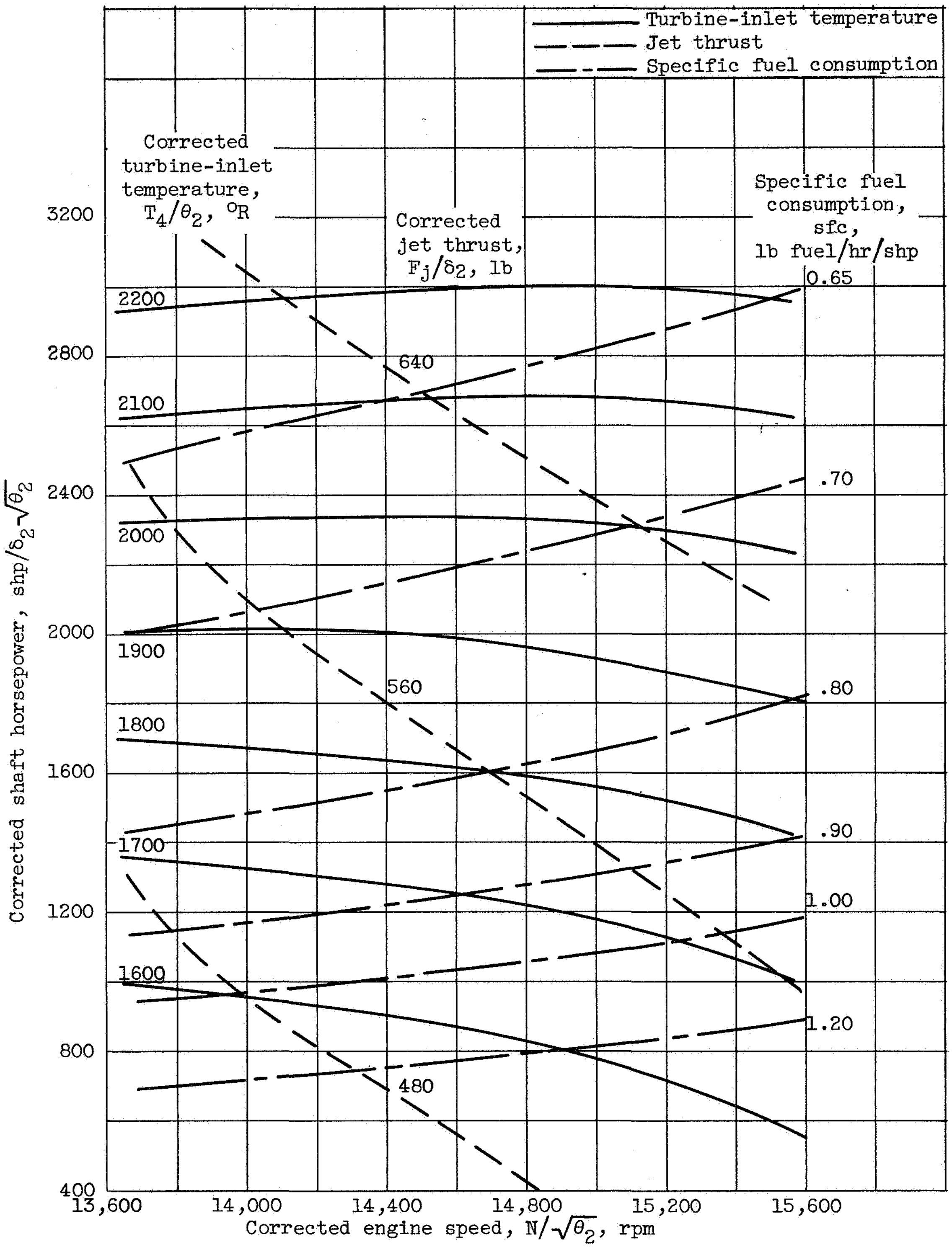


Figure 5. - Effect of corrected engine speed on corrected air flow. Altitude, 15,000 feet; flight Mach number, 0.303.



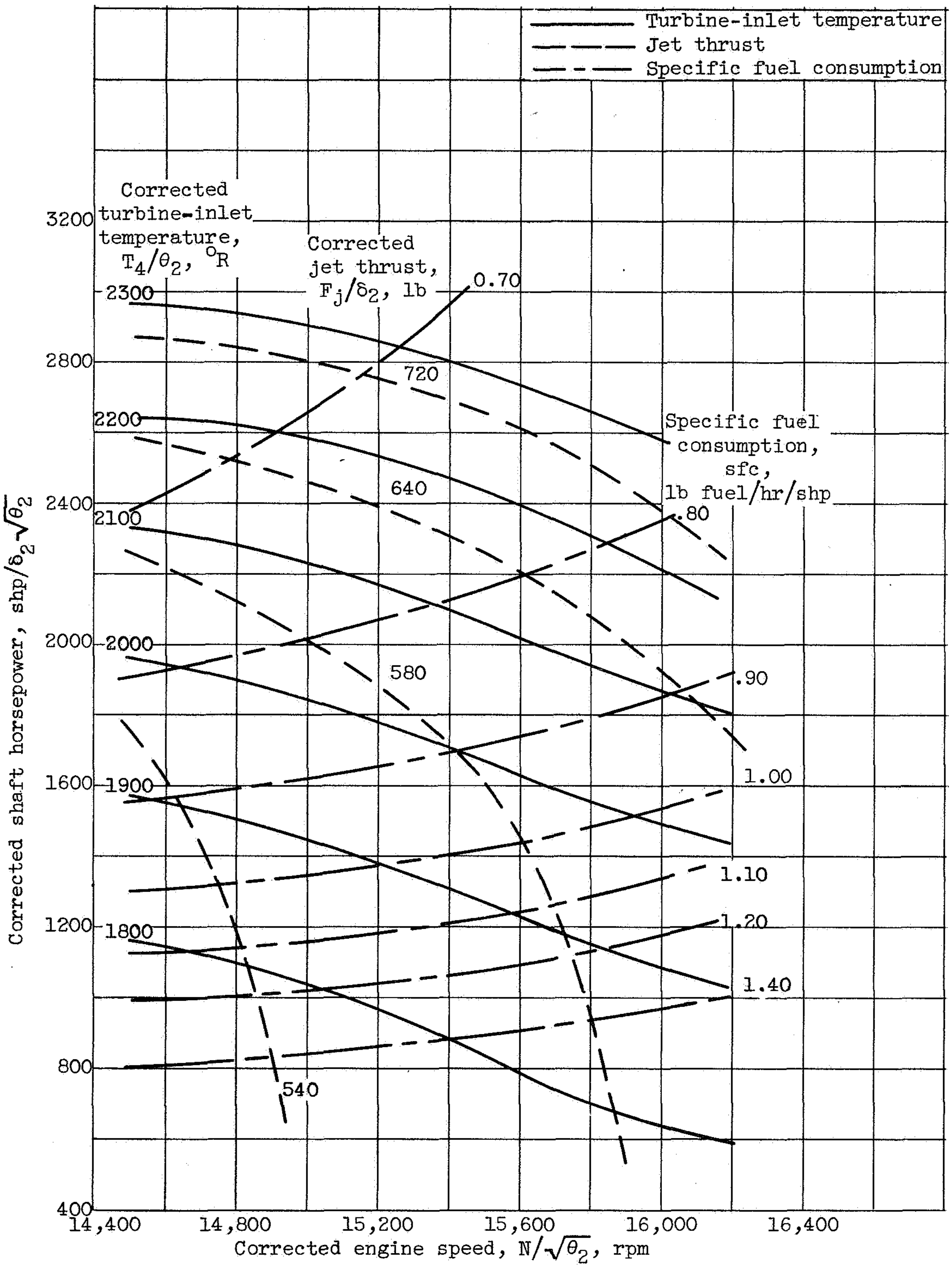
(a) Altitude, 5000 feet; flight Mach number, 0.30.

Figure 6. - Engine-performance map.



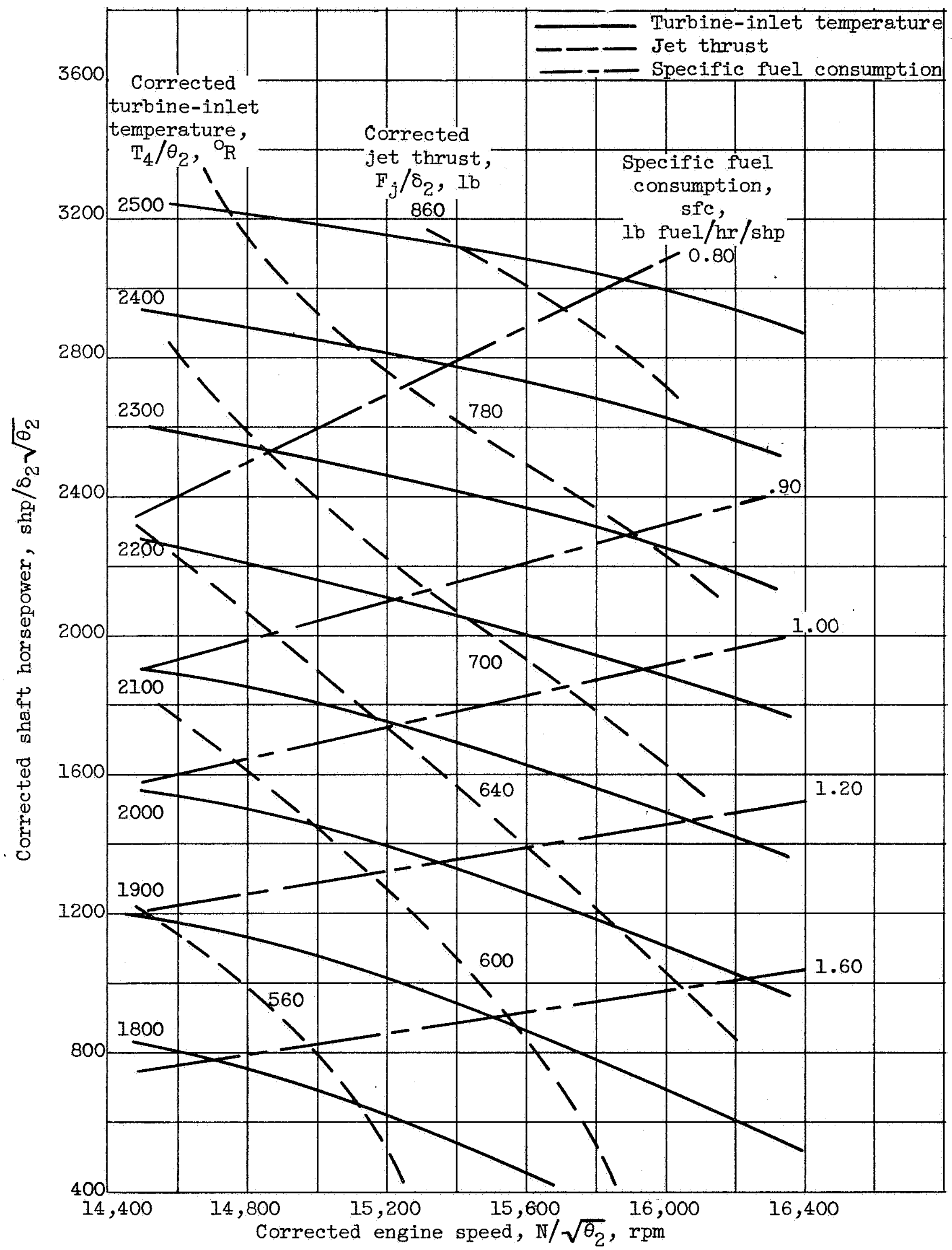
(b) Altitude, 15,000 feet; flight Mach number, 0.303.

Figure 6. - Continued. Engine-performance map.



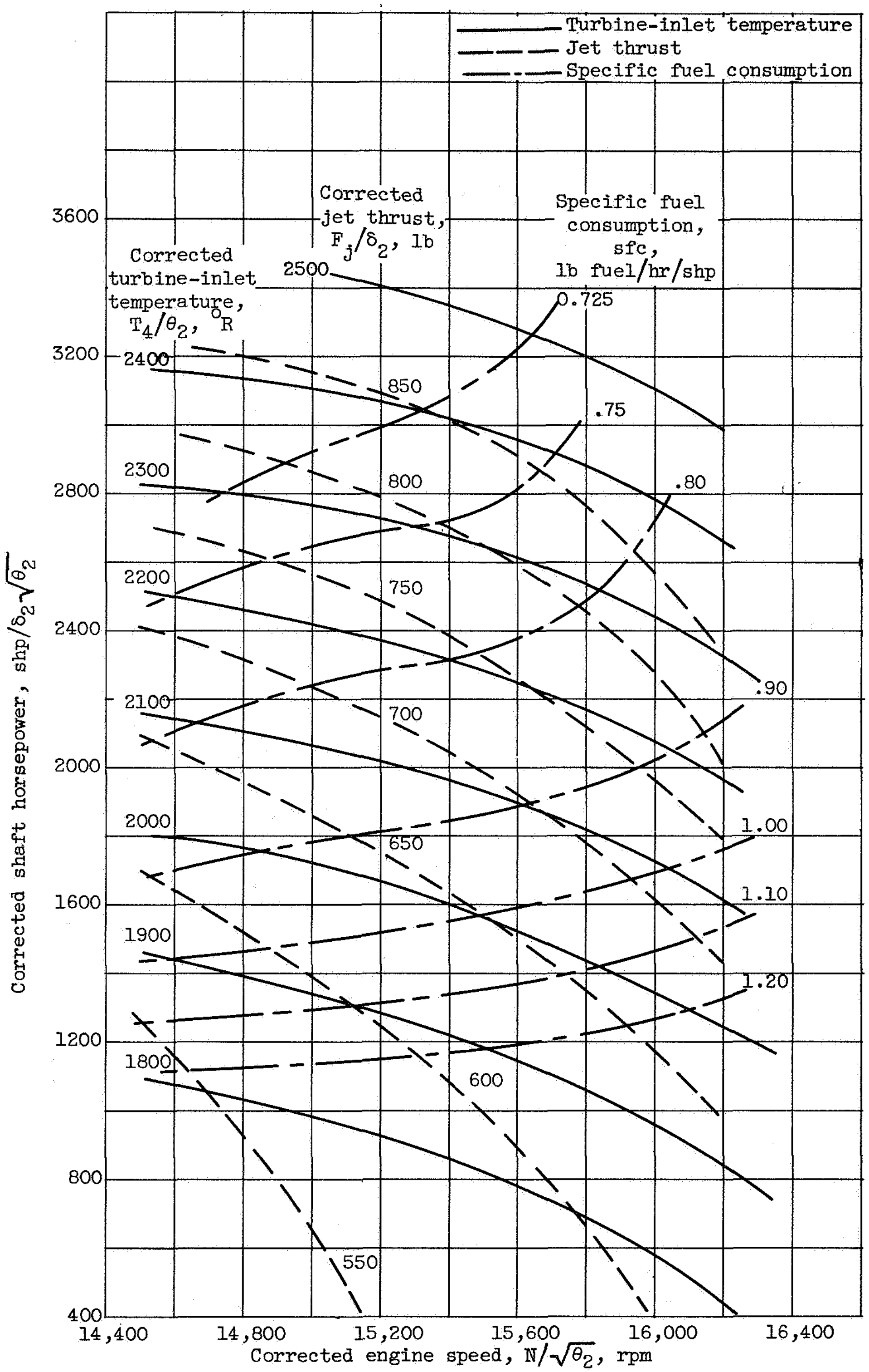
(c) Altitude, 25,000 feet; flight Mach number, 0.291.

Figure 6. - Continued. Engine-performance map.



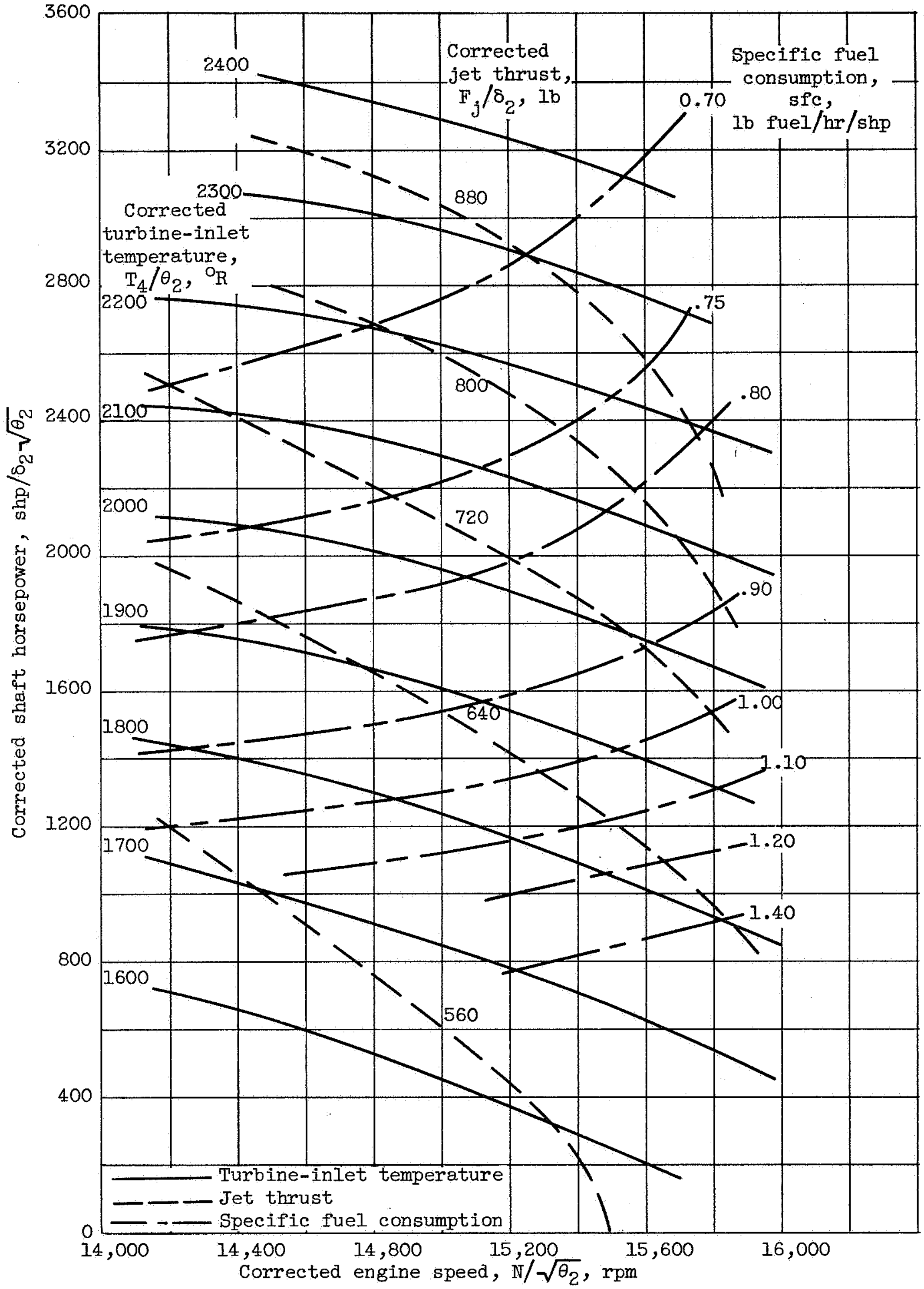
(d) Altitude, 35,000 feet; flight Mach number, 0.301.

Figure 6. - Continued. Engine-performance map.



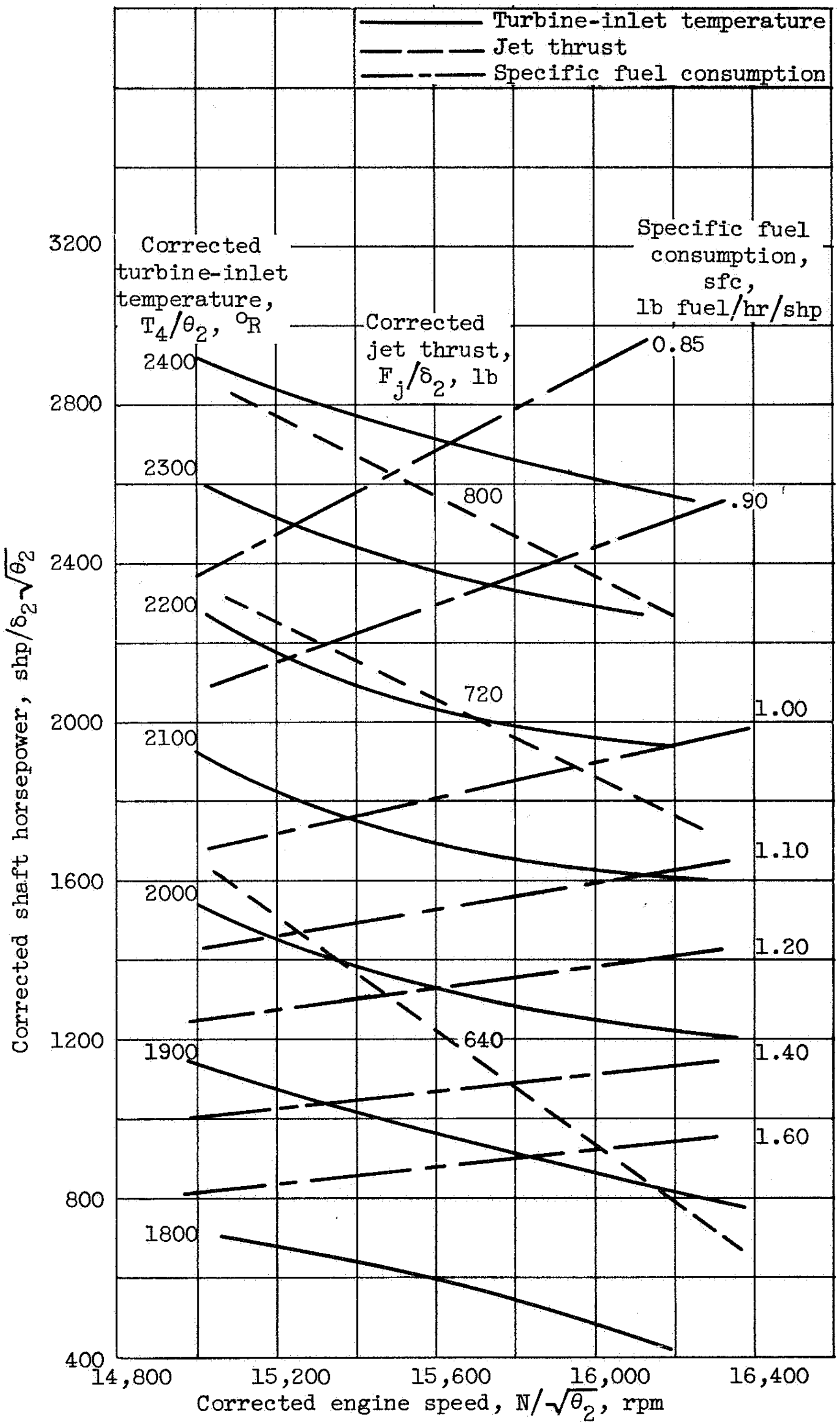
(e) Altitude, 35,000 feet; flight Mach number, 0.438.

Figure 6. - Continued. Engine-performance map.



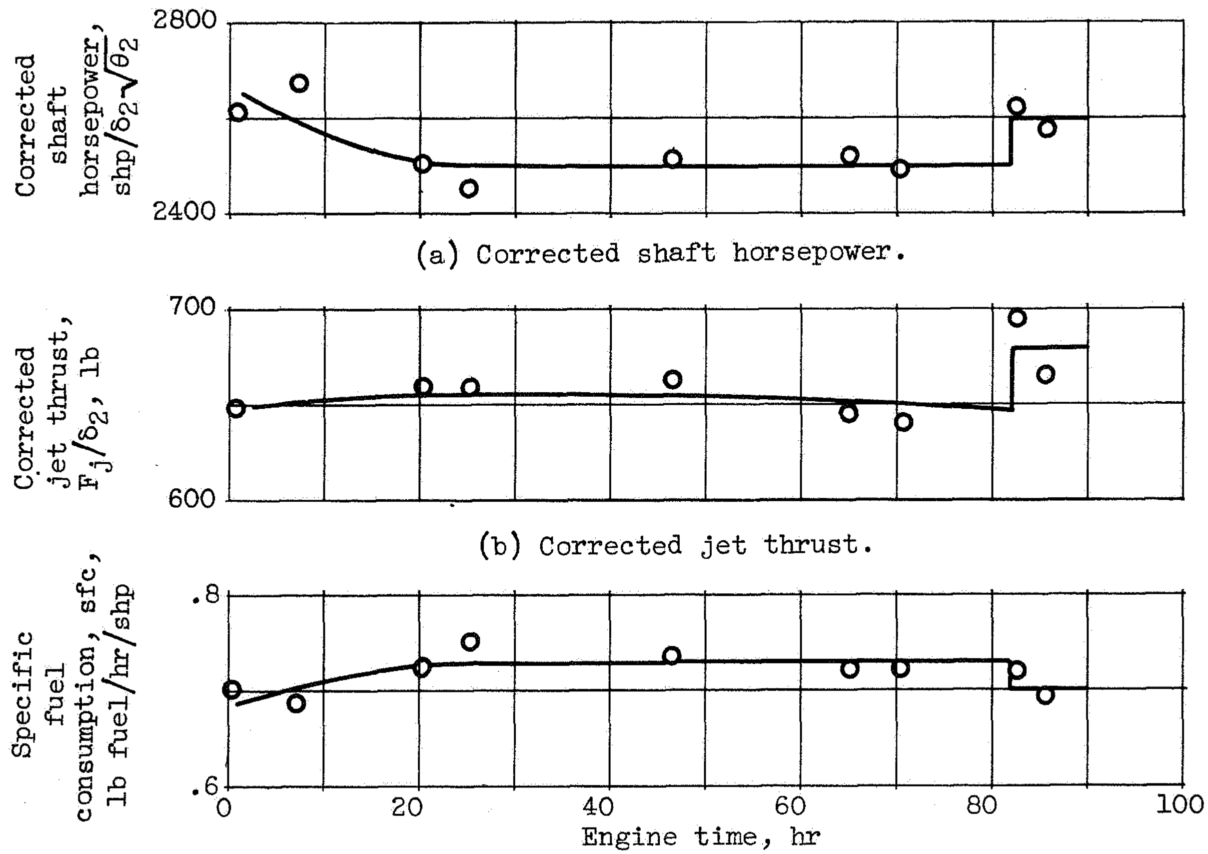
(f) Altitude, 35,000 feet; flight Mach number, 0.557.

Figure 6. - Continued. Engine-performance map.



(g) Altitude, 45,000 feet; flight Mach number, 0.294.

Figure 6. - Concluded. Engine-performance map.



(a) Corrected shaft horsepower.

(b) Corrected jet thrust.

(c) Specific fuel consumption.

Figure 7. - Effect of engine time on engine performance. Altitude, 25,000 feet; flight Mach number, 0.29; average corrected engine speed, 15,110 rpm; average corrected turbine-inlet temperature, 2185° R.

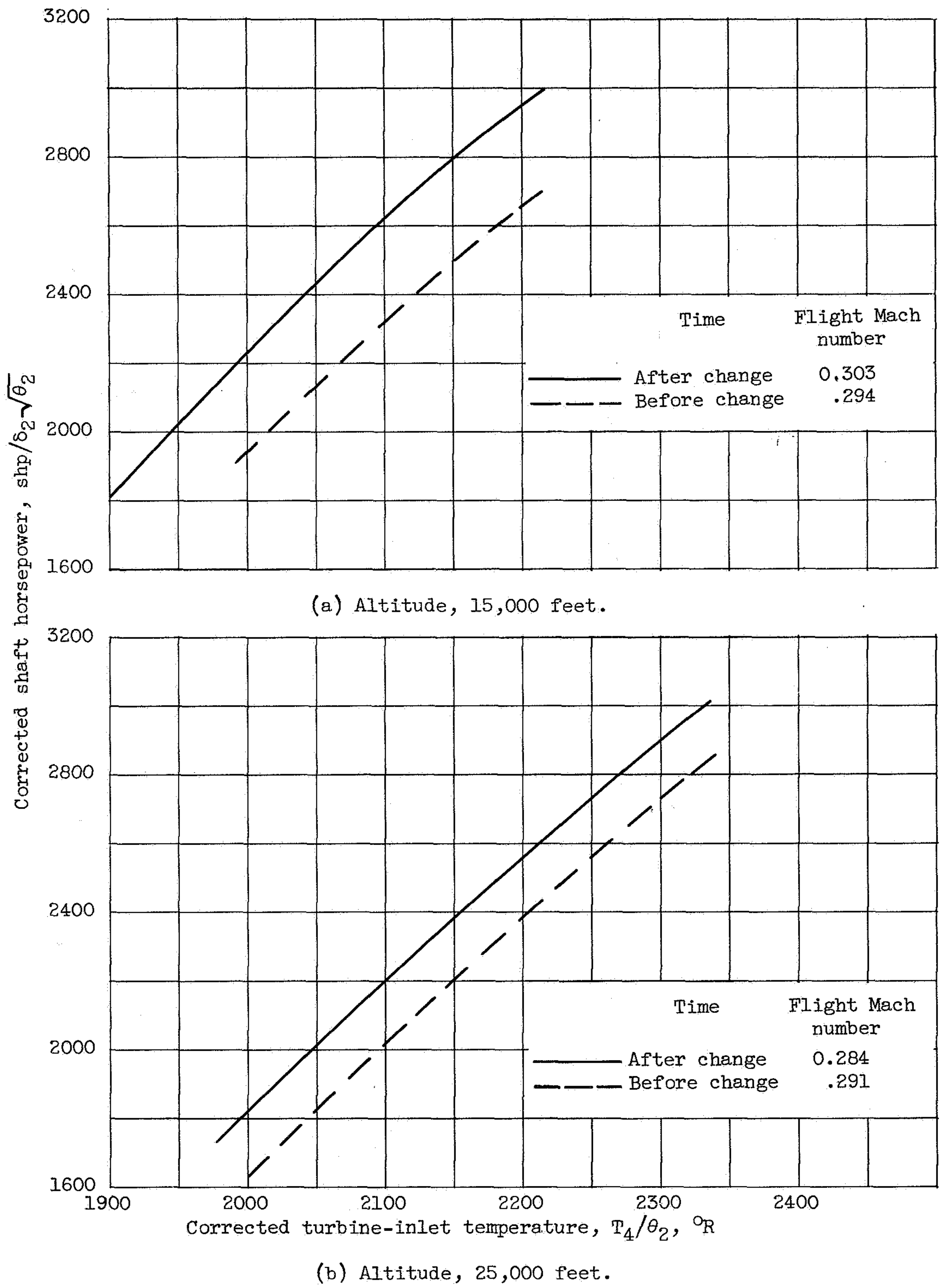
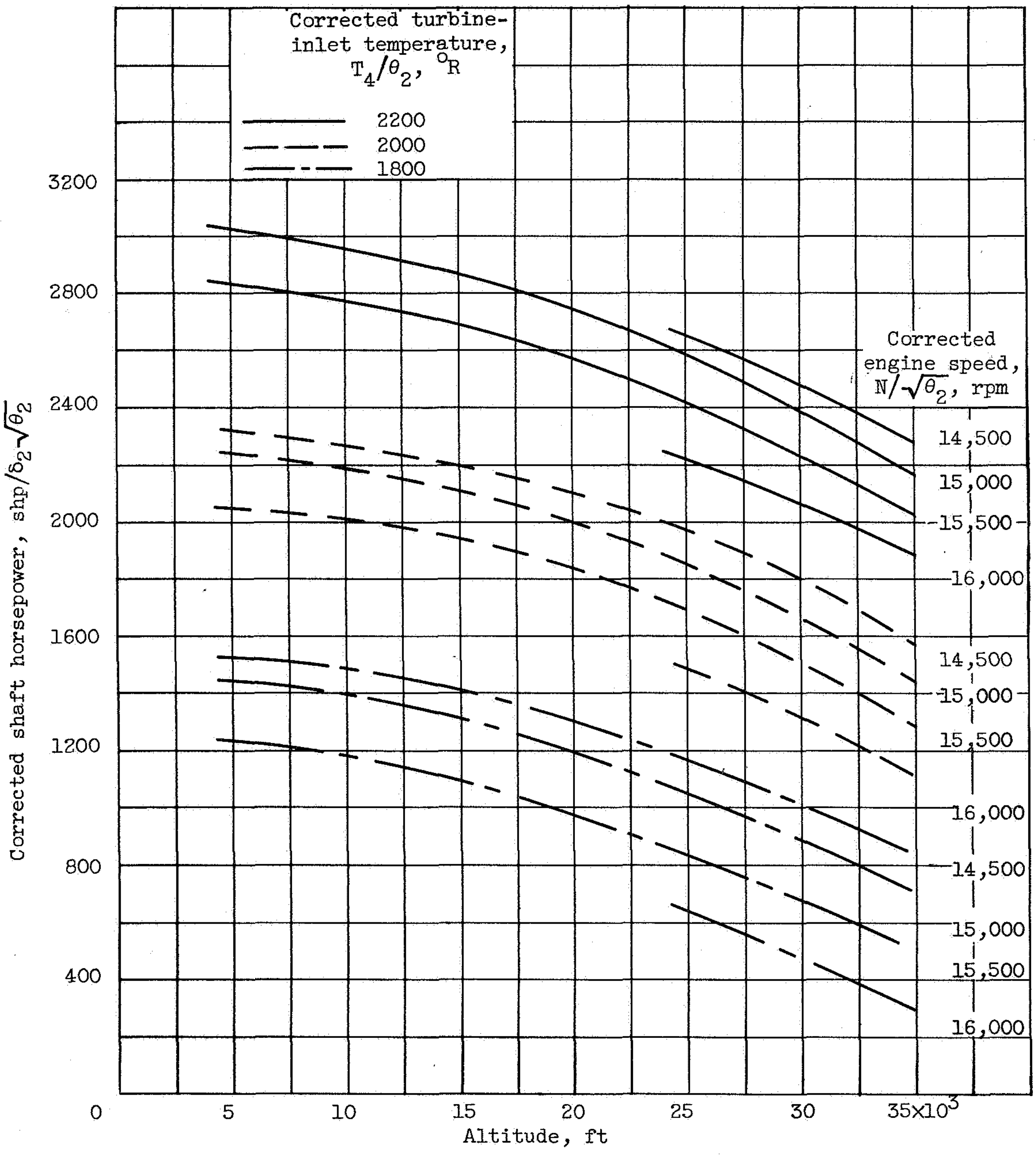
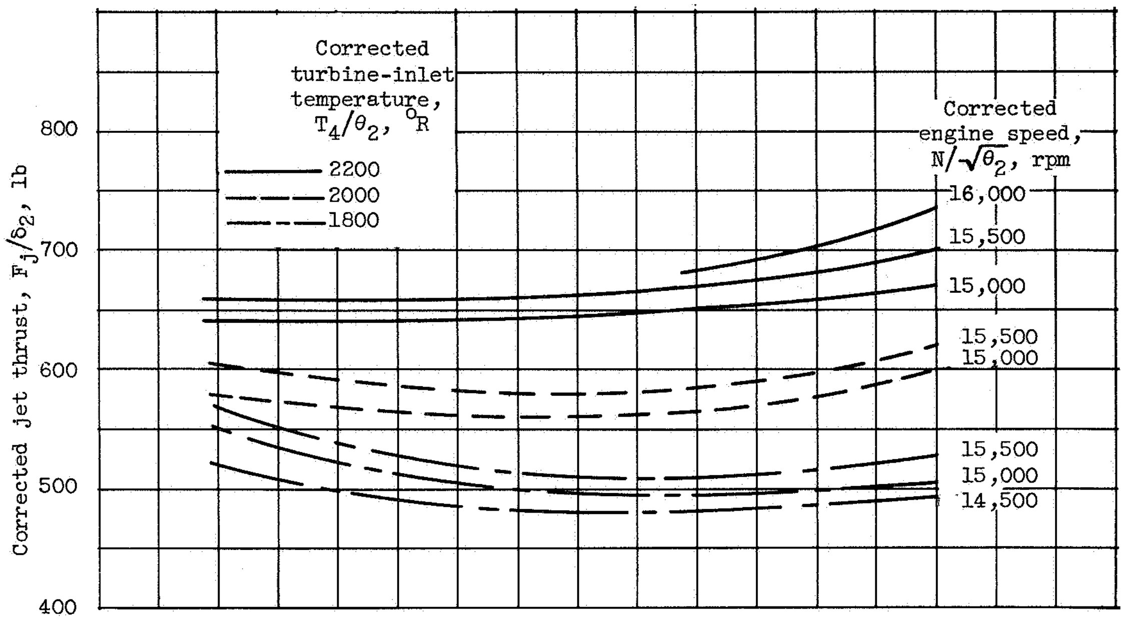


Figure 8. - Effect of turbine change on engine performance. Corrected engine speed, 15,610 rpm.

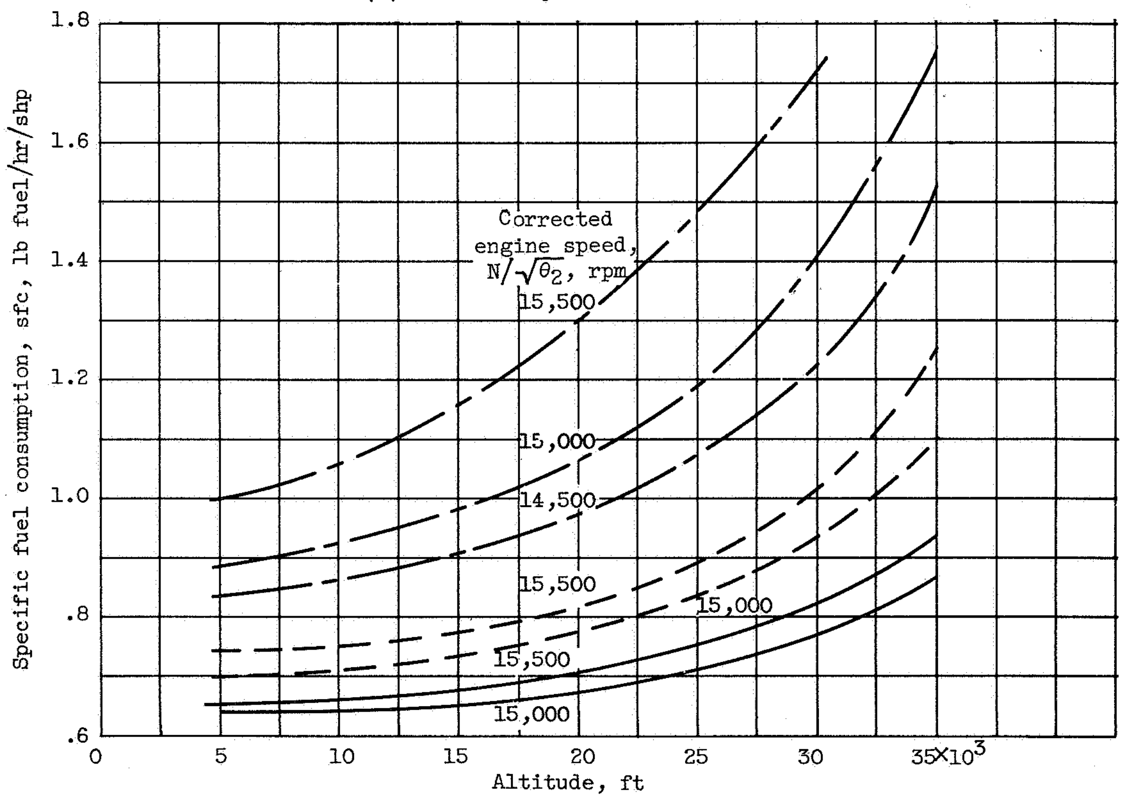


(a) Corrected shaft horsepower.

Figure 9. - Effect of altitude on engine performance. Flight Mach number, 0.30.



(b) Corrected jet thrust.



(c) Specific fuel consumption.

Figure 9. - Concluded. Effect of altitude on engine performance. Flight Mach number, 0.30.

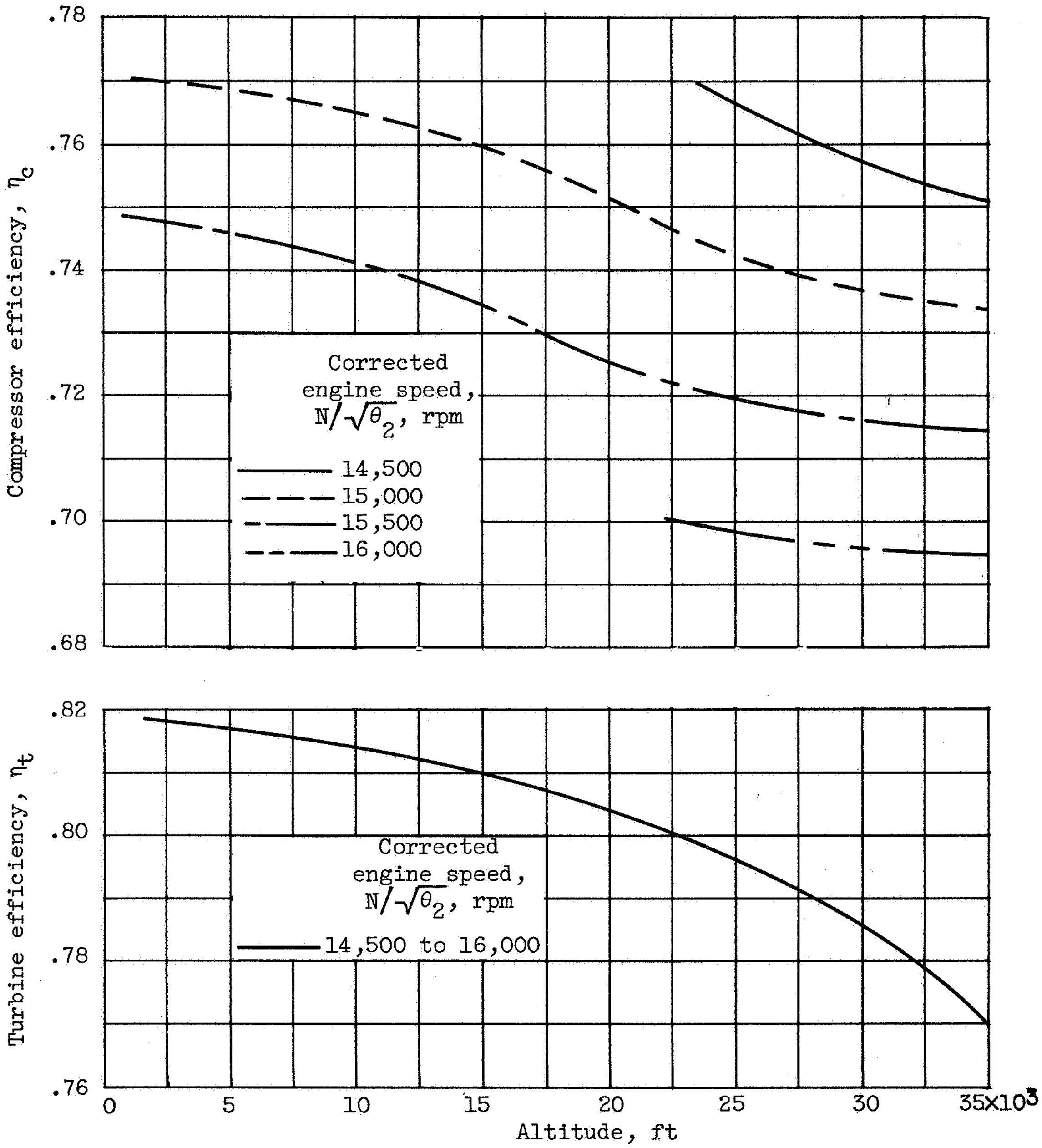
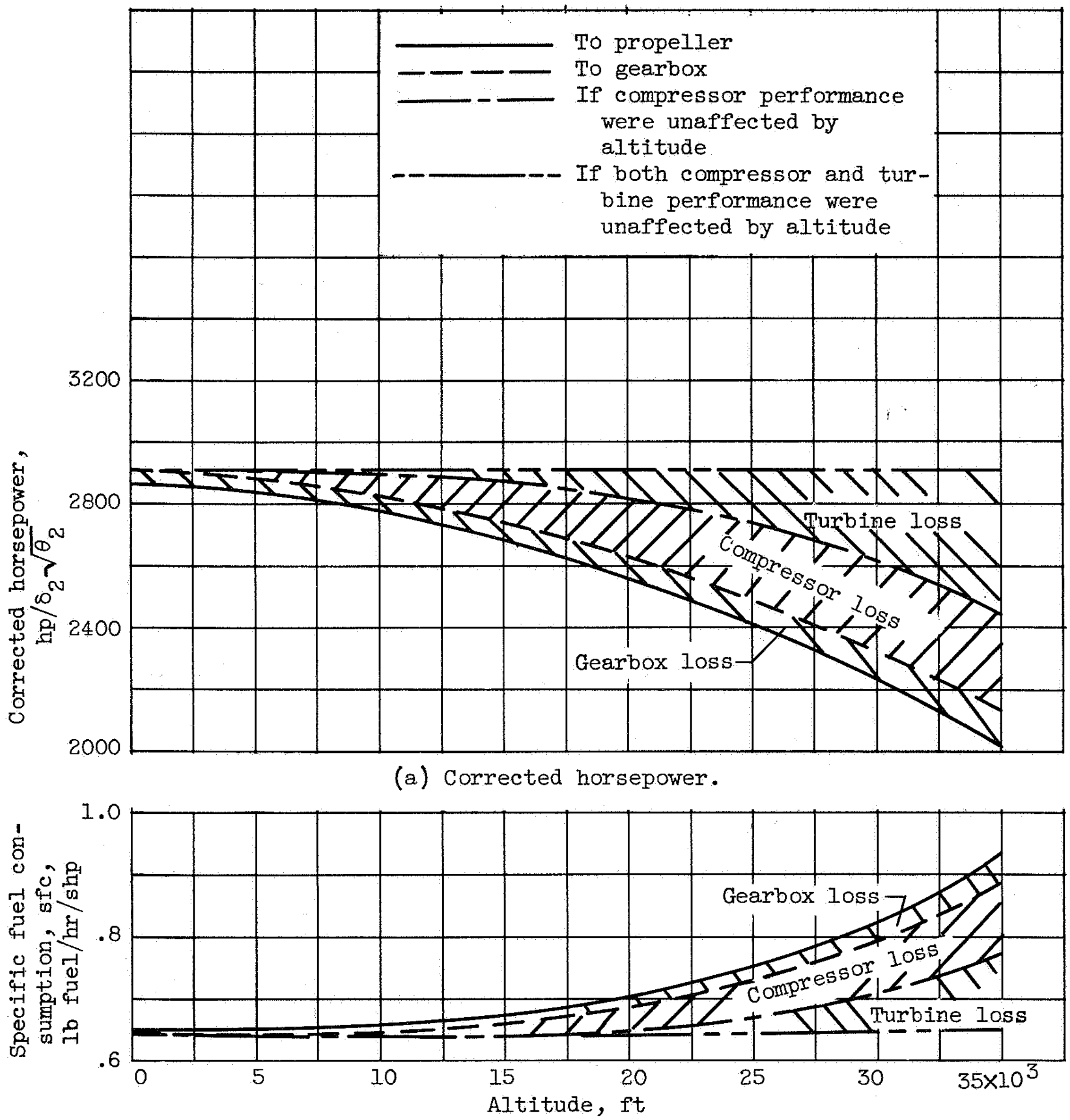


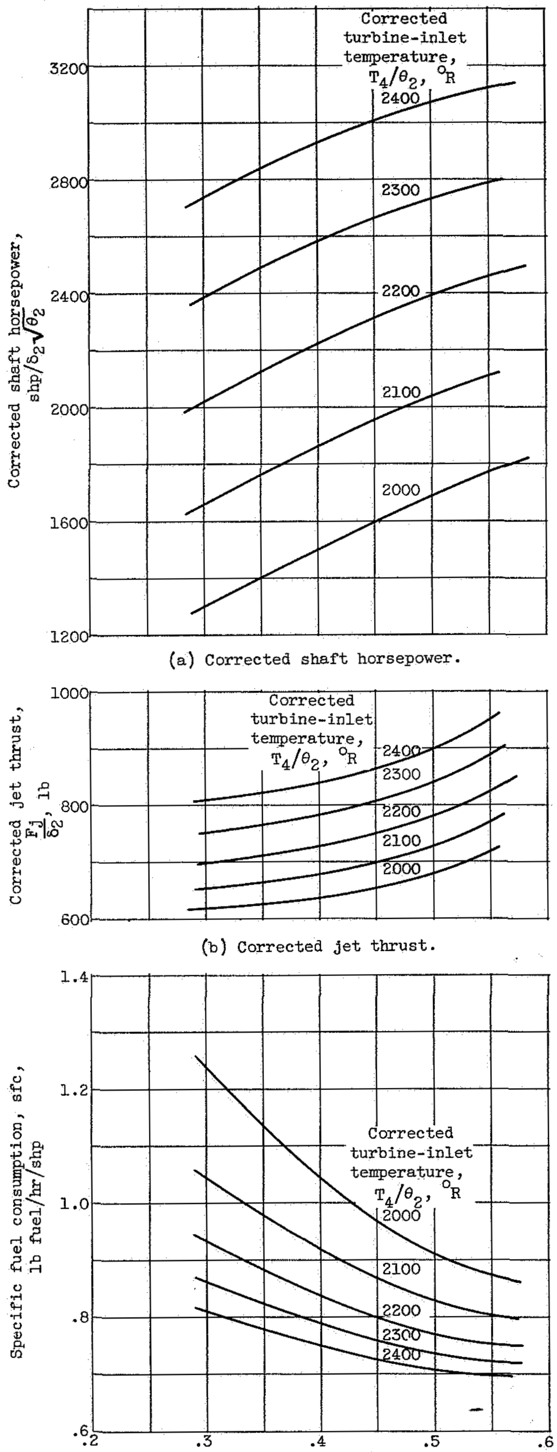
Figure 10. - Effect of altitude on compressor and turbine efficiency. Flight Mach number, 0.30; corrected turbine-inlet temperature, 2200° R.



(a) Corrected horsepower.

(b) Specific fuel consumption.

Figure 11. - Effect of component performance on engine performance; corrected engine speed, 15,500 rpm, corrected turbine-inlet temperature, 2200° R; flight Mach number, 0.30.



(a) Corrected shaft horsepower.

(b) Corrected jet thrust.

(c) Specific fuel consumption.

Figure 12. - Effect of flight Mach number on engine performance. Altitude, 35,000 feet; corrected engine speed, $N/\sqrt{\theta_2}$, 15,500 rpm.

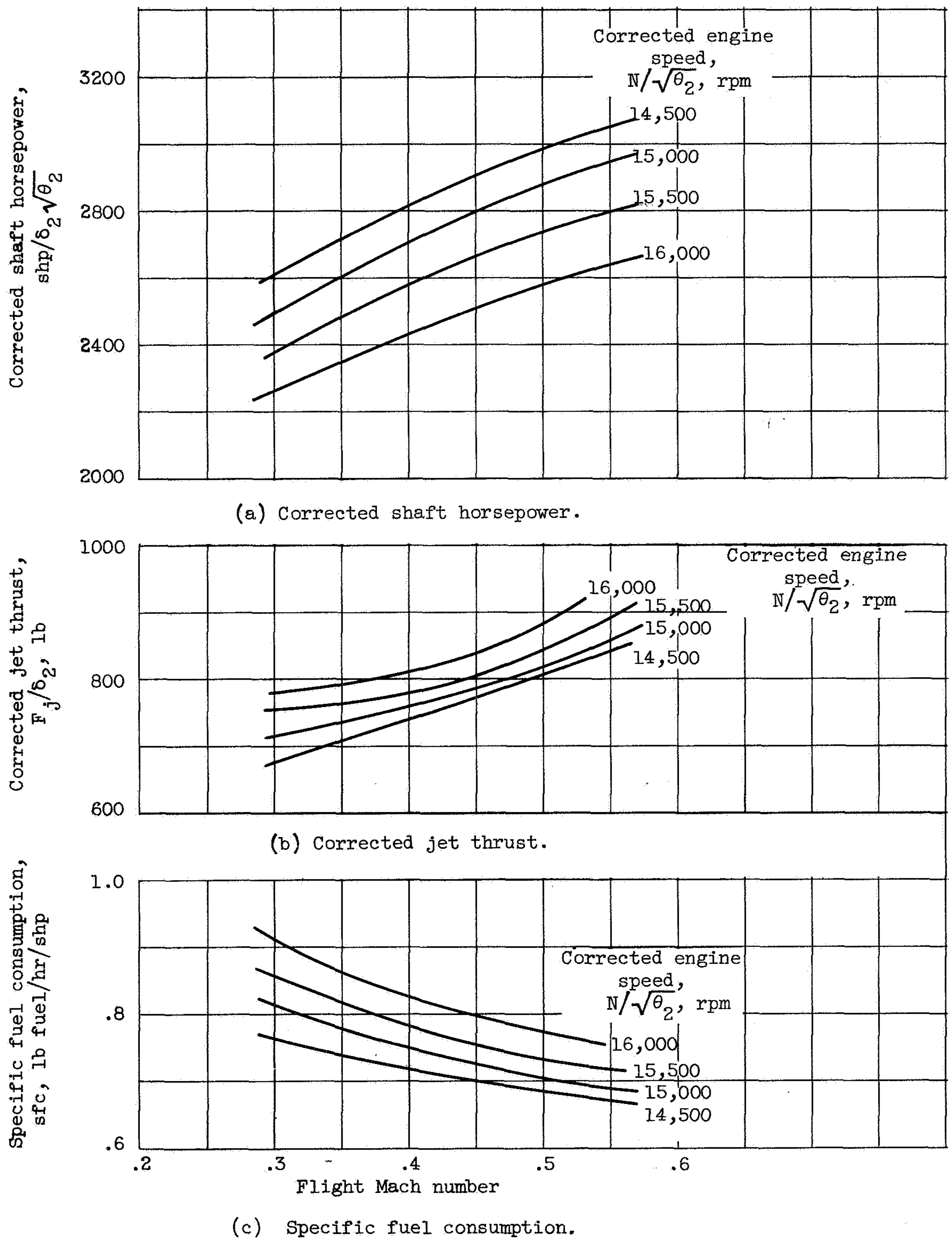
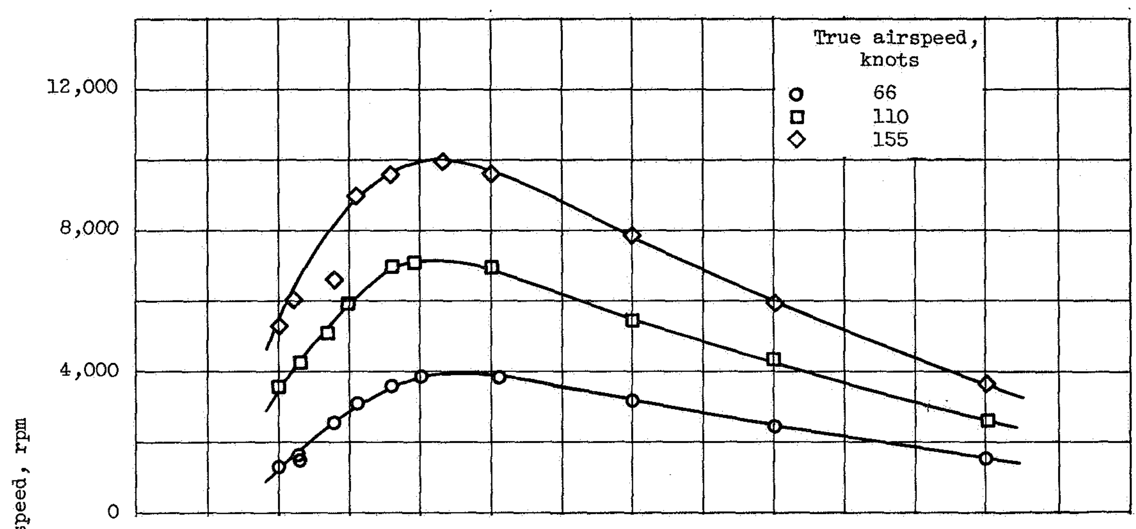
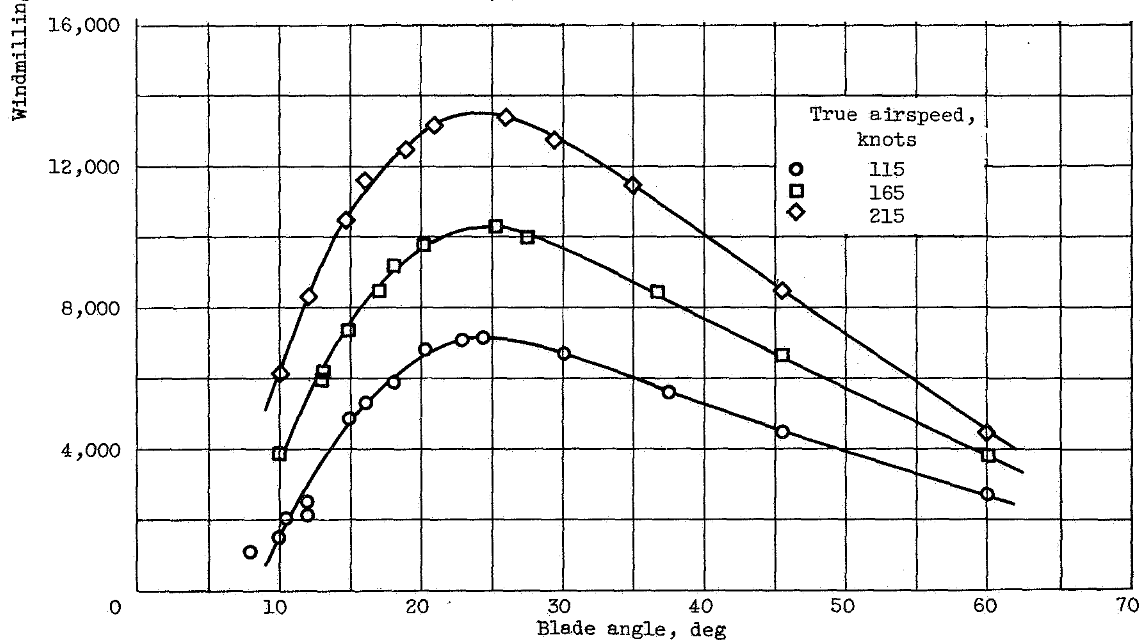


Figure 13. - Effect of flight Mach number on engine performance. Altitude, 35,000 feet; corrected turbine-inlet temperature, T_4/θ_2, 2300° R.



(a) Altitude, 15,000 feet.



(b) Altitude, 35,000 feet.

Figure 14. - Effect of blade angle on windmilling speed at various true airspeeds.

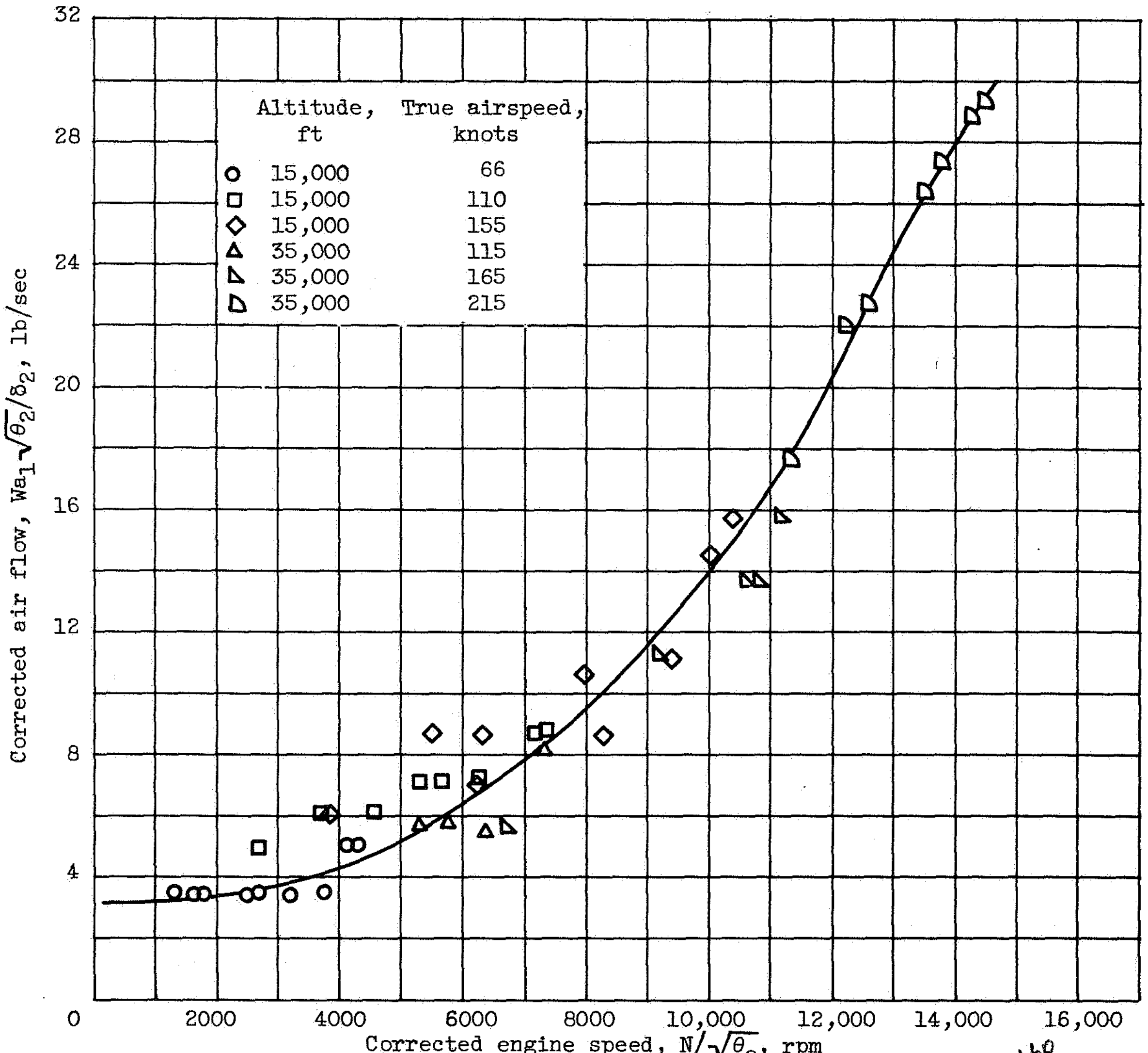


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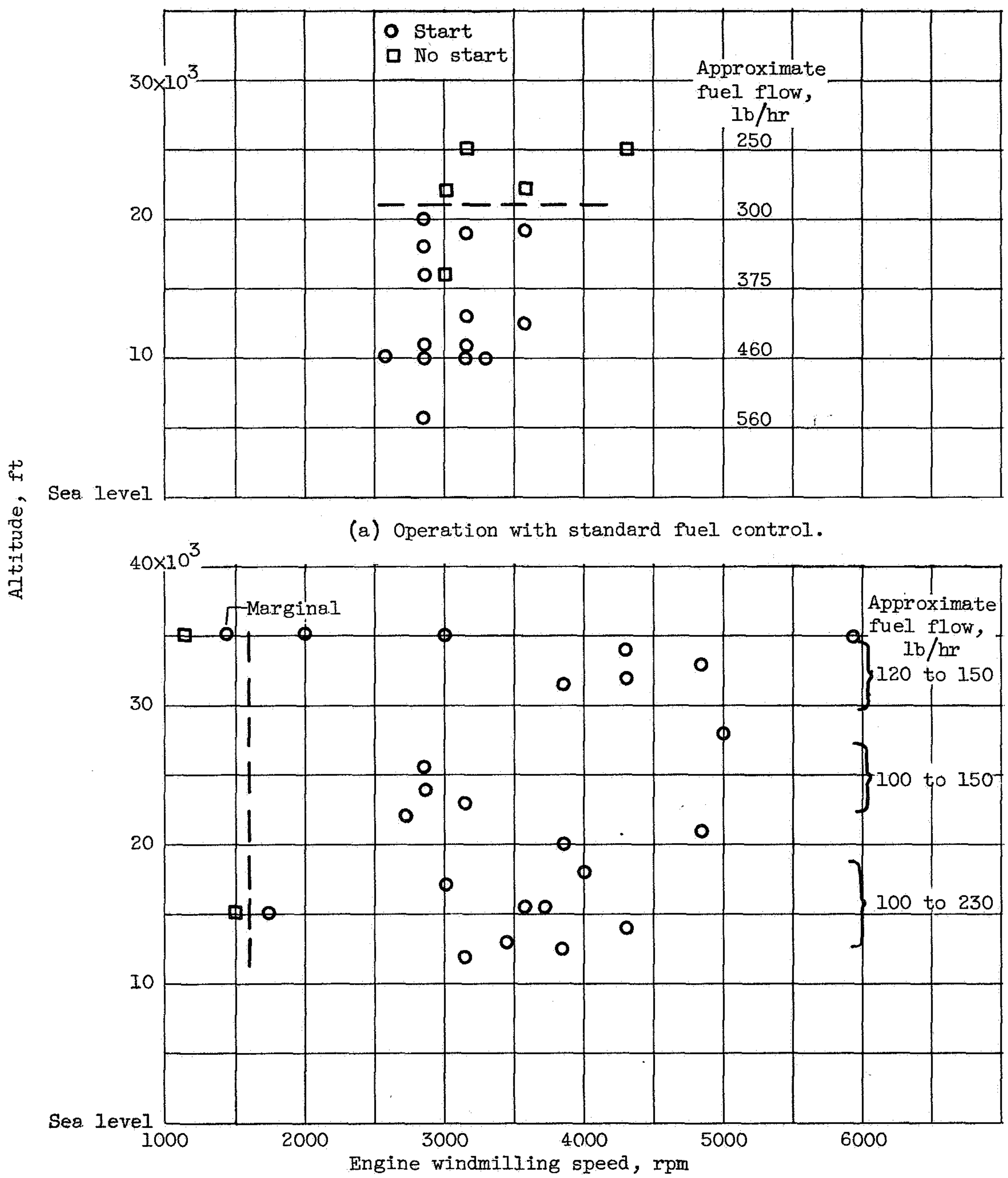
Figure 15. - Variation of corrected air flow with corrected engine speed for engine in windmilling condition.



(b) Operation with second fuel control.

Figure 16. - Effect of altitude, windmilling engine speed, and fuel system on engine starts.